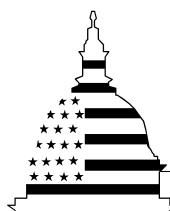


March 2005

# DEFENSE ACQUISITIONS

## Assessments of Selected Major Weapon Programs



G A O

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Highlights of [GAO-05-301](#), a report to congressional committees

## Why GAO Did This Study

The Department of Defense (DOD) is embarking on a number of efforts to enhance warfighting and the way the department conducts business. Major investments are being made to develop improved weapon systems to combat various threats to U.S. security. While the weapons that DOD ultimately develops have no rival in superiority, weapon systems acquisition remains a long-standing high-risk area. GAO's reviews over the past 30 years have found consistent problems with weapon acquisitions such as cost increases, schedule delays, and performance shortfalls. In addition, DOD faces several budgetary challenges that underscore the need to deliver its new major weapon programs within estimated costs and to obtain the most from those investments. DOD can help resolve these problems by using a more knowledge-based approach for developing new weapons.

This report provides congressional and DOD decision makers with an independent, knowledge-based assessment of selected defense programs that identifies potential risks and needed actions when a program's projected attainment of knowledge diverges from the best practice. It can also highlight those programs that employ practices worthy of emulation by other programs. GAO plans to update and issue this report annually.

[www.gao.gov/cgi-bin/getrpt?GAO-05-301](http://www.gao.gov/cgi-bin/getrpt?GAO-05-301).

To view the full product, including the scope and methodology, click on the link above. For more information, contact Paul L. Francis at (202) 512-4841 or francisp@gao.gov.

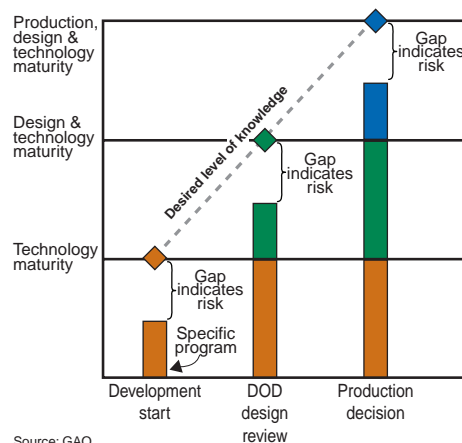
## DEFENSE ACQUISITIONS

### Assessments of Selected Major Weapon Programs

## What GAO Found

GAO assessed 54 programs, which represent an investment of over \$800 billion, ranging from the Missile Defense Agency's Airborne Laser to the Army's Warfighter Information Network-Tactical. GAO's assessments are anchored in a knowledge-based approach to product development that reflects best practices of successful programs. This approach centers on attaining high levels of knowledge in three elements of a new product or weapon—technology, design, and production—at key consecutive junctures in development. If a program is not attaining these levels of knowledge, it incurs increased risk of technical problems, with significant potential cost and schedule growth implications (see figure). If a program is falling short in one element, like technology maturity, it is harder to attain the requisite amount of knowledge to prudently proceed in succeeding elements.

**Attainment of Product Knowledge**



The majority of programs GAO assessed are costing more and taking longer to develop than planned. Most of the programs proceeded with less knowledge at critical junctures than suggested by best practices, although some programs came close to meeting best practice standards. For example, technology and design for the F/A-22 matured late in the program contributing to large cost growth and schedule delays. The JASSM program, in contrast, has achieved a high level of knowledge at critical junctures while experiencing minimal cost increases or schedule delays.

Managing these levels of knowledge takes on additional significance as DOD's share of the discretionary budget faces increasing pressure from the growth in mandatory spending and the demands of ongoing military operations. For these reasons, if DOD approves programs with low levels of knowledge and accepts the attendant likely adverse cost and schedule consequences, it will probably get fewer quantities for the same investment or face difficult choices on which investments it cannot afford to pursue.

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**Abbreviations**

ACTS	AEHF Comsec/Transec System
BAMS	Broad Area Maritime Surveillance
BTERM	Ballistic Trajectory Extended Range Munition
DARPA	Defense Advanced Research Projects Agency
DCMA	Defense Contract Management Agency
DOD	Department of Defense
EKV	exoatmospheric kill vehicle
FY	fiscal year
GAO	Government Accountability Office
GEO	geosynchronous earth orbit
GPS	Global Positioning System
HEO	highly elliptical orbit
HLV	heavy lift vehicle
IMIS	Integrated Maintenance Information System
ISR	intelligence, surveillance and reconnaissance
JDAM	Joint Direct Attack Munition
JSSEO	Joint Single Integrated Air Picture Systems Engineering Organization
MDA	Missile Defense Agency
NA	not applicable
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NOAA	National Oceanic and Atmospheric Administration
OT&E	Operational Test and Evaluation
PDR	Preliminary Design Review
RDT&E	Research, Development, Test, and Evaluation
SDACS	Solid Divert and Attitude Control System
SM-3	Standard Missile 3
TBD	to be determined
TF/TA	Terrain Following and Terrain Avoidance
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
UHF	ultra high frequency
U.S.C.	United States Code
USMC	United States Marine Corps

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## Contents

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**United States Government Accountability Office  
Washington, D.C. 20548**

March 31, 2005

**Congressional Committees**

Fiscal realities demand that the Department of Defense (DOD) get better outcomes from its weapon system investments. Federal discretionary spending, along with other federal policies and programs, will face serious budget pressures in the coming years. While providing for the common defense is in the Constitution, defense spending is considered “discretionary” from a budget sense. Furthermore, investments in new capabilities such as weapon systems are more discretionary than other aspects of defense spending, such as personnel costs and the costs of supporting and maintaining current force operations. As a result, it is imperative that DOD’s limited resources be allocated to the most appropriate weapon system investments based on current and reasonably expected threats and that the investments yield the results promised (such as performance, cost, and timing) within the constraints imposed by those resources.

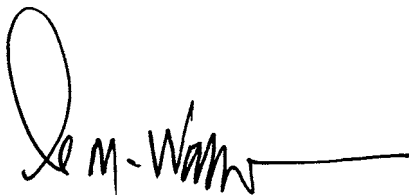
We have assessed weapon acquisitions as a high-risk area since 1990. Although U.S. weapons are the best in the world, the programs to acquire them often take significantly longer and cost significantly more money than promised and often deliver fewer quantities and other capabilities than planned. It is not unusual for estimates of time and money to be off by 20 to 50 percent. When costs and schedules increase, quantities are cut, and the value for the warfighter—as well as the value of the investment dollar—is reduced. In these times of asymmetric threats and netcentricity, individual weapon system investments are getting larger and more complex. Just 4 years ago, the top five weapon systems cost about \$281 billion; today, in the same base year dollars, the top five weapon systems cost about \$521 billion. If these megasystems are managed with traditional margins of error, the financial consequences can be dire, especially in light of a constrained discretionary budget.

Our work on the development of successful commercial and defense products has shown that it is possible to get better outcomes from investments if decisions are based on high levels of knowledge. Defense acquisition policies support such an approach to managing weapon system programs. However, actual practice is not yet consistently following written policy. As this annual assessment of major weapon acquisitions shows, most programs are proceeding with inadequate levels of knowledge, with attendant increased risks for traditional rates of cost

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growth, along with schedule delays and performance shortfalls. On the other hand, this assessment also includes programs that are proceeding with high levels of knowledge, showing that practice can follow policy.

This is our third annual assessment of weapon system programs. The experiences catalogued in this report provide insights on how programs can be better positioned to succeed. To the extent that programs are not so positioned, the report can be used by decision makers to take actions to reduce risks by building higher levels of knowledge.

A handwritten signature in black ink, appearing to read "D. M. Walker", followed by a horizontal line.

David M. Walker  
Comptroller General  
of the United States



United States Government Accountability Office  
Washington, D.C. 20548

March 31, 2005

## Congressional Committees

The Department of Defense (DOD) is embarking on a number of efforts to enhance warfighting capabilities. Primary among these efforts are the investments being made to develop improved weapon systems with technological superiority and enhanced lethality to combat threats to U.S. security. Investment in programs such as the Army's Future Combat Systems and Warfighter Information Network-Tactical, the Missile Defense Agency's suite of land, sea, air, and space systems, the Navy's advanced ships such as the DD(X) Destroyer, and the Air Force's space systems such as the Transformational Satellite Communications System are likely to dominate the budget and doctrinal debate well into the next decade. Many of these embody the dual challenge of employing complex technology with a rapid pace of development. Fiscal realities, coupled with the larger scope of key acquisitions, reduce the ability of budgets to accommodate typical margins for error in terms of cost increases and schedule delays. Identifying risks early and addressing them before they become problems can lessen cost increases and schedule delays and thus enable budgets to buy what was planned.

In this report, we assess 54 programs that represent an investment of approximately \$800 billion.<sup>1</sup> Our objective is to provide decision makers with independent, knowledge-based assessments of individual systems' attained knowledge and potential risks.

## A Challenging Time for Weapon System Investments

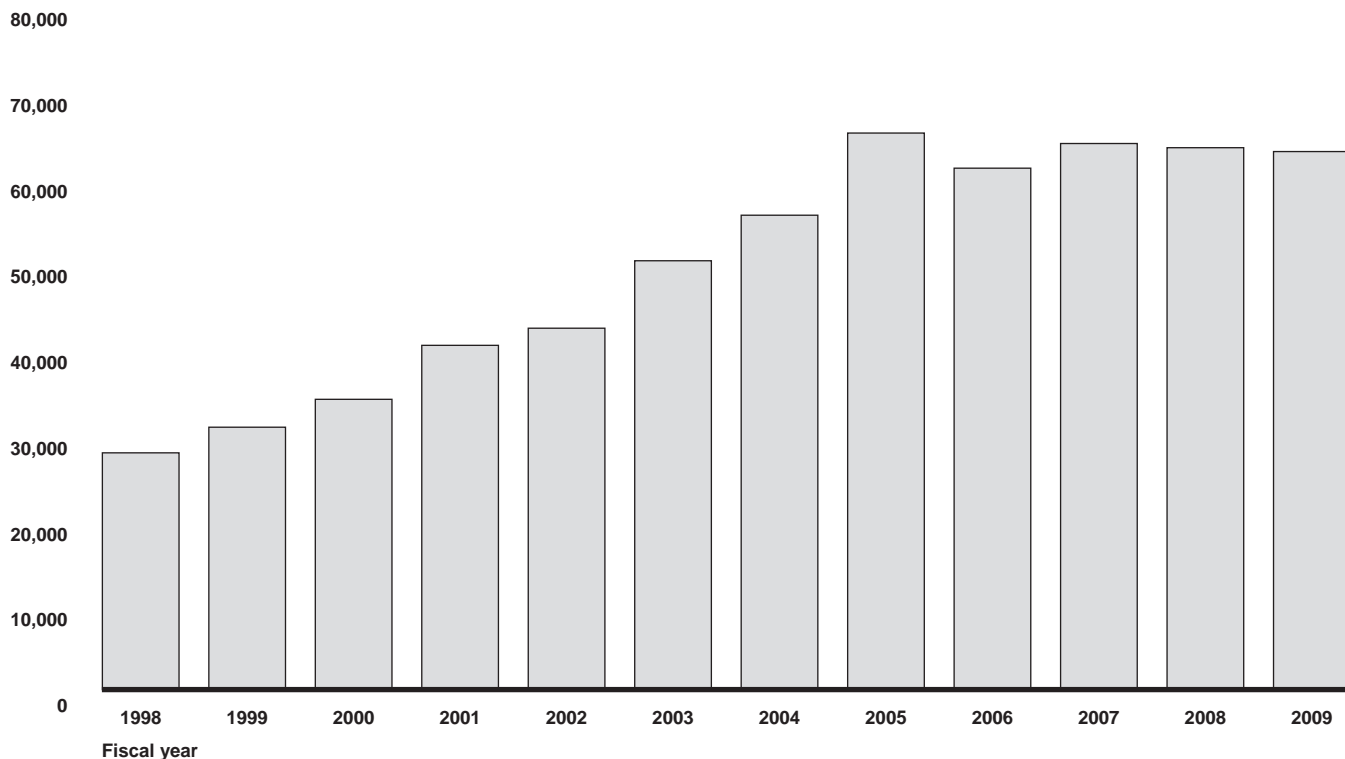
DOD has entered a period of high investment. A significant portion of this investment is for the acquisition of weapon systems that offer technologically advanced capabilities. The investment in the research, development, and procurement of major weapon systems is expected to rise from \$144 billion in fiscal year 2005 to \$185 billion in fiscal year 2009. Major Defense Acquisition Programs make up about 45 percent, or

<sup>1</sup> This estimate includes total research, development, test, and evaluation (RDT&E); procurement; military construction; and acquisition operation and maintenance appropriations to develop the weapon systems.

\$65 billion, as shown in figure 1, of the fiscal year 2005 investment request.<sup>2</sup> DOD's total planned investment in these programs is approximately \$1.3 trillion, with about \$812 billion of that investment yet to be made.

**Figure 1: RDT&E and Procurement Funding—Major Defense Acquisition Programs**

In millions of constant 2005 dollars



Source: GAO analysis of DOD data.

There are several challenges to getting the most from that investment. First, because DOD's investment in weapon systems represents one of the largest discretionary items in the federal budget, DOD's budget faces

<sup>2</sup> Major Defense Acquisition Programs are programs identified by DOD as programs that require eventual RDT&E expenditures of more than \$365 million or \$2.19 billion in procurement in fiscal year 2000 constant dollars.

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growing pressures from increases in mandatory federal spending.<sup>3</sup> According to the Congressional Budget Office, federal deficits are expected to average \$250 billion through fiscal year 2009 and new budgetary demands stemming from demographic trends lie beyond that time frame. In calendar year 2004, discretionary spending accounted for about 39 percent of the federal budget, and current projections show that because of increases in mandatory spending, discretionary spending is likely to decrease to 33 percent of the federal budget by fiscal year 2009.<sup>4</sup> It will be difficult for DOD to increase its budget share to cover cost increases in weapon programs in that environment.

Second, DOD faces competing demands within its own budget, such as from operations in Afghanistan and Iraq. Since September 2001, DOD has needed \$158 billion in supplemental appropriations to support the global war on terrorism.<sup>5</sup> The budget implications of these operations further increase the demand made of the defense dollar and therefore the investment in new weapon programs. For example, current military operations are causing faster wear on existing weapons, which will need refurbishment or replacement sooner than planned. These needs will compete with the investment in new weapon programs.

Third, DOD programs typically take longer to develop and cost more to buy than planned, placing additional demands on available funding. These programs increasingly compete for resources and are sometimes forced to make trade-offs in quantities, resulting in a reduction of buying power. As a result, funds are not available for other competing needs and programs yield fewer quantities for the same, if not higher, cost. Table 1 illustrates seven programs with the greatest reduction of buying power. Some of these programs experienced higher costs for the same initial quantity.







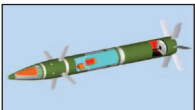
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<sup>3</sup> Mandatory spending is controlled by laws other than appropriation acts. Discretionary spending is provided in appropriations acts.

<sup>4</sup> Congressional Budget Office, *The Budget and Economic Outlook: Fiscal Years 2006 to 2015*. (Washington, D.C.: January 2005.)

<sup>5</sup> Estimate as of May 2004. Another supplemental was expected in January 2005 to cover costs of operations in Iraq and Afghanistan.

**Table 1: Examples of Programs with Reduced Buying Power**

Program		Initial investment	➡	Initial quantity	Latest investment	➡	Latest quantity	Percent unit cost increase
Joint Strike Fighter		\$183.6 billion		2,866 aircraft	\$198.6 billion		2,457 aircraft	26.2
Future Combat Systems		79.8 billion		15 units	108 billion		15 units	35.2
F/A-22 Raptor		78.4 billion		648 aircraft	73.1 billion		279 aircraft	116.5
Evolved Expendable Launch Vehicle		14.9 billion		181 vehicles	27.8 billion		138 vehicles	143.8
Space Based Infrared System High		3.9 billion		5 satellites	9.9 billion		5 satellites	149.9
Expeditionary Fighting Vehicle		7.9 billion		1,025 vehicles	9.5 billion		1,025 vehicles	21.0
Extended Range Guided Munition		389.3 million		8,570 munitions	598.4 million		3,141 munitions	319.4

Source: GAO analysis of DOD data. Images sourced in their respective order: JSF Program Office; Program Manager, Unit of Action, U.S. Army; F/A-22 System Program Office; (Left) © 2003 ILS/Lockheed Martin, (right) © 2003 The Boeing Company; Lockheed Martin Space Systems Company; General Dynamics Land Systems; Naval Gunnery Project Office.

If DOD cannot deliver its major new programs within estimated costs, difficult choices have to be made regarding which investments to pursue and which to discontinue.

Current Programs Are Costing More and Taking Longer to Develop

The majority of programs in our assessment are costing more and taking longer to develop than estimated. As shown in table 2, total RDT&E costs for 26 common set<sup>6</sup> weapon programs increased by nearly \$42.7 billion, or 42 percent, over the original business case (the first full estimate). The same programs have also experienced an increase in the time needed to develop capabilities with a weighted-average schedule increase of nearly 20 percent.<sup>7</sup>

Table 2: Cost and Cycle Time Growth for 26 Weapon Systems

Billions of constant 2005 dollars			
	First full estimate	Latest estimate	Percent change
Total cost	\$479.6	\$548.9	14.5
RDT&E cost	102.0	144.7	41.9
Weighted-average acquisition cycle time <sup>a</sup>	146.6 months	175.3 months	19.6

Source: GAO analysis of DOD data.

<sup>a</sup>This is a weighted estimate of average acquisition cycle time for the 26 programs based on total program costs at the first full and latest estimates. The simple average for these two estimates was 94.9 months for the first full estimate and 114.7 months for the latest estimate, resulting in a 20.8 percent change.

Quantities for 10 of the common set programs have been reduced since their first estimate.<sup>8</sup> In addition, the weighted-average program acquisition unit cost of 25 of the 26 programs increased by roughly 50 percent.<sup>9</sup>

<sup>6</sup> The common set refers to the 26 weapon system programs that we were able to assess since development began and between annual assessment periods. The 26 programs are AESA, AEHF, APKWS, C-5 AMP, C-5 RERP, CH-47F, CEC, E-2 AHE, EA-18G, Excalibur, EFV, ERGM, F/A-22, FCS, Global Hawk, JASSM, JSOW, JSF, JTRS Cluster 1, Land Warrior, NPOESS, Tomahawk, SDB, V-22, WIN-T, and WGS. We limited this analysis to these 26 programs because all data including cost, schedule, cycle time, and quantities were available for comparison between program estimates.

<sup>7</sup> A weighted average gives more expensive programs a greater value.

<sup>8</sup> The 10 programs are AEHF, C-5 AMP, C-5 RERP, Excalibur, ERGM, F/A-22, Global Hawk, JSF, JSOW, and V-22.

<sup>9</sup> This estimate is a weighted average based on total program cost and does not include the Excalibur program because of its extreme unit cost growth. The simple average program unit cost increase for the same 25 programs is 40 percent. The weighted average, including the Excalibur, is 52 percent.

During the last year, cost and schedule estimates for the same 26 programs have increased noticeably since our last assessment, as shown in table 3.

**Table 3: Cost and Cycle Time for the Same Programs: 2004 Assessment and 2005 Assessment**

Billions of constant 2005 dollars			
	2004 assessment	2005 assessment	Percent change
Total cost	\$480.3	\$548.9	14.3
RDT&E cost	127.3	144.7	13.7
Weighted-average acquisition cycle time <sup>a</sup>	166.1 months	175.3 months	5.5

Source: GAO analysis of DOD data.

<sup>a</sup>This is a weighted estimate of average acquisition cycle time for the 26 programs based on total program cost estimates for the 2004 assessment and the 2005 assessment. The simple average for these two estimates was 110.7 months for the 2004 assessment and 114.7 months for the 2005 assessment, resulting in a 3.6 percent change.

<sup>b</sup>These estimates also include the Land Warrior program. Although this program was not included in the 2004 assessment, the program is included in the common set because data were available from the December 2002 Selected Acquisition Report for inclusion in this estimate.

Some of DOD's largest programs have driven these increases. For example, research and development costs for the Army's Future Combat Systems, a \$108 billion investment, increased by approximately 51 percent over the past year while in the midst of a major restructuring of the program. Likewise, the Joint Strike Fighter, a \$199 billion investment, has reported a research and development cost increase of over 19 percent in the past year.

## A Knowledge-Based Approach Can Lead to Better Acquisition Outcomes

Over the last several years we have undertaken a body of work that examines weapon acquisition issues from a perspective that draws upon lessons learned from best system development practices. We found that successful programs take steps to gather knowledge that confirms that their technologies are mature, their designs stable, and their production processes are in control. Separating technology development from product development is important to this effort. Successful programs make a science and technology organization, rather than the program or product development manager, responsible for maturing technologies. Such steps can help to reduce costs and deliver a product on time and within budget. DOD's current acquisition guidance embraces the use of evolutionary, knowledge-based acquisition practices proven to be more effective and efficient in developing new products. By fully implementing these practices, DOD can better leverage its investments by shortening the time it

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takes to develop capabilities with more predictable costs and schedules, thereby maintaining its buying power.

Successful product developers ensure a high level of knowledge was achieved at key junctures in development. We characterize these junctures as knowledge points. These knowledge points and associated indicators are defined as follows:

- **Knowledge point 1:** Resources and needs match. This level of knowledge occurs when a sound business case is made for the product—that is, a match is made between the customer’s requirements and the product developer’s available resources in terms of knowledge, time, and money. Achieving a high level of technology maturity at the start of system development is an important indicator of whether this match has been made. This means that the technologies needed to meet essential product requirements have been demonstrated to work in their intended environment.
- **Knowledge point 2:** Product design is stable. This level of knowledge occurs when a program determines that a product’s design is stable—that is, it will meet customer requirements and cost and schedule targets. A best practice is to achieve design stability at the system-level critical design review, usually held midway through development. Completion of at least 90 percent of engineering drawings at the system design review provides tangible evidence that the design is stable.
- **Knowledge point 3:** Production processes are mature. This level of knowledge is achieved when it has been demonstrated that the product can be manufactured within cost, schedule, and quality targets. A best practice is to ensure that all key manufacturing processes are in statistical control—that is, they are repeatable, sustainable, and capable of consistently producing parts within the product’s quality tolerances and standards—at the start of production.

The attainment of each successive knowledge point builds on the preceding one. While the knowledge itself builds continuously without clear lines of demarcation, the attainment of knowledge points is sequential. In other words, production maturity cannot be attained if the design is not stable, and design stability cannot be attained if the critical technologies are not mature.

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Seeking to improve acquisition outcomes, DOD revised its acquisition policy in May 2003 to incorporate a knowledge-based, evolutionary framework. The policy adopts lessons learned from successful commercial companies. For example, the policy attempts to separate technology development from product development and requires the demonstration of technologies to high readiness levels. The policy also allows managers to develop a product in increments rather than trying to incorporate all of the desired capabilities in the first version that comes off the production line.

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## Most Programs Have Proceeded with Lower Levels of Knowledge at Critical Junctures

Most of the programs we reviewed proceeded with lower levels of knowledge at critical junctures and attained key elements of product knowledge later in development than specified in DOD policy, which resulted in cost increases and schedule delays.

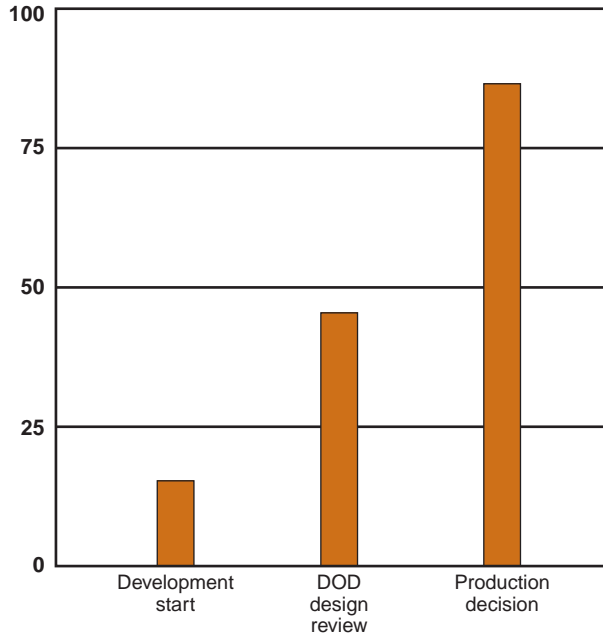
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### Development Start

Our work shows that the demonstration of technology maturity by the start of system development is the key measure for achievement of knowledge point 1. A program that proceeds into product development without demonstrating mature technologies does so with increased risk of cost growth and schedule delays throughout the life of the program.

Only 15 percent of the programs we assessed began development having demonstrated all of their technologies mature, as illustrated in figure 2.

**Figure 2: Percent of Programs That Achieved Technology Maturity at Key Junctures**



Source: GAO analysis.

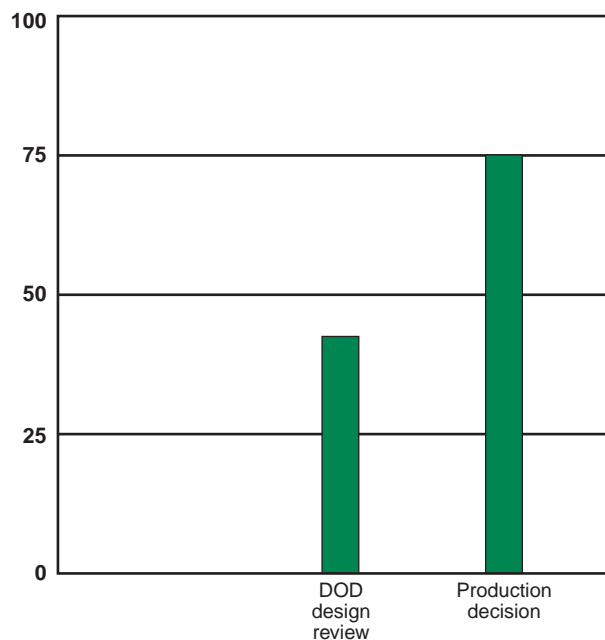
More often than not, programs sought to mature technologies well into system development when they should have focused on maturing system design and preparing for production. The programs that started development with mature technologies experienced lower development and unit cost increases than those programs that started development with immature technologies. For example, RDT&E costs for the programs that started development with mature technology increased by an average of 9 percent over the first full estimate, whereas the development costs for the programs that started development with immature technologies increased an average of 41 percent over the first full estimate. Likewise, program acquisition unit costs for the programs with mature technology increased by less than 1 percent, whereas the programs that started development with immature technologies experienced an average program acquisition

unit cost increase of nearly 21 percent over the first full estimate.<sup>10</sup> Finally, the programs with mature technology experienced an average schedule delay of 7 months—a 9 percent increase—whereas the schedule for the programs that started development with immature technology increased an average of 13 months—a 13 percent increase.

## Design Review

As illustrated in figure 3, 42 percent of the programs that held a design review achieved design stability at that key juncture.

**Figure 3: Percent of Programs Achieving Design Stability at Key Junctures**



Source: GAO analysis.

<sup>10</sup> These percentages are program cost weighted averages. The simple average increase for program acquisition unit costs is 0.68 percent for the programs that started development with mature technologies and 25 percent for the programs that started development with immature technologies.

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With the exception of the Navy's V-22, which has experienced significant design changes since development start in 1986, these programs have experienced a 6 percent increase in development costs and an average schedule increase of 11 months since the first full estimate.<sup>11</sup> Those programs that did not achieve design stability have experienced a combined development cost increase of 46 percent and an average schedule increase of 29 months since the first full estimate.<sup>12</sup>

Design stability cannot be attained if key technologies are not mature. Ten programs held design review without demonstrating mature critical technologies.<sup>13</sup> Out of the 10 programs, 7 had experienced a cost increase, schedule delay, or both.<sup>14</sup> The unit cost of 5 of these programs increased by at least 10 percent.<sup>15</sup> In contrast, 3 programs entered product development with mature technologies. These three programs kept program unit cost increases to a minimum, with costs either falling or increasing by single digits.<sup>16</sup>

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<sup>11</sup> This estimate does not include cost and schedule data for three programs: the V-22, Aegis BMD, and STSS. Aegis BMD and STSS were not included in the cost and schedule estimates because they are missile defense elements that do not provide baseline cost and schedule estimates against which to measure progress.

<sup>12</sup> The cost and schedule estimates do not include the THAAD system or the Ground-Based Midcourse Defense system because they are missile defense elements that do not provide baseline estimates against which to measure progress. The schedule estimate does not include the ATIRCM/CMWS because a key date is classified.

<sup>13</sup> The 10 programs are AESA, Aegis BMD, APKWS, ATIRCM/CMWS, EFV, ERGM, F/A-22, GMD, JTRS 1, and STSS. The F/A-22 held its design review in 1995 and while we did not formally assess the technology maturity at that point, the F/A-22 technologies and design matured late in the program (e.g. the F/A-22 program had released 21 percent of drawings at design review).

<sup>14</sup> This estimate does not include the missile defense elements (Aegis BMD, GMD, and STSS) because they do not provide baseline estimates against which to measure progress.

<sup>15</sup> The five programs are AESA, ATIRCM/CMWS, EFV, ERGM, and F/A-22.

<sup>16</sup> The three programs are the C-5 RERP, JASSM, and the Tactical Tomahawk. C-5 RERP and JASSM were assessed to have design stability at design review. C-5 RERP had a program unit cost increase of 8.2 percent; JASSM had a program unit cost of increase of 7.1 percent; and Tactical Tomahawk had a decrease of program unit cost of -13.5 percent.

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Nine programs are scheduled to hold their system design review in the next year.<sup>17</sup> Only two of those programs, the B-2 Radar Modernization and the Excalibur program, expect their technologies to be mature at the time of their design reviews. The remaining seven programs project that their technologies will not attain maturity until after their critical design reviews.

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## Production Start

To determine if a product's design is reliable and producible, successful programs use statistical process control to bring manufacturing processes under control so they are repeatable, sustainable, and consistently producing parts within quality standards. The collection of process control data prior to a production decision can enable a smooth transition from product development to the production phase. Of the 19 programs in production or approaching a production decision in the next year, only 2 collected or plan to collect statistical process control data to measure the maturity of production processes.<sup>18</sup> While the absence of the data does not mean that production processes were immature, it does prevent an assessment against an objective standard.

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## How to Read the Knowledge Graphic for Each Program Assessed

We assess each program in 2 pages and depict the extent of knowledge in a stacked bar graph and provide a narrative summary at the bottom of the first page. As illustrated in figure 4, the knowledge graph is based on the three knowledge points and the key indicators for the attainment of knowledge: technology maturity (depicted in orange), design stability (depicted in green), and production maturity (depicted in blue). A “best practice” line is drawn based on the ideal attainment of the three types of knowledge at the three knowledge points. In some cases, we obtained projections from the program office of future knowledge attainment. These projections are depicted as dashed bars. The closer a program's attained knowledge is to the best practice line, the more likely the weapon will be delivered within estimated cost and schedule. A knowledge deficit at the start of development—indicated by a gap between the technology knowledge attained and the best practice line—means the program proceeded with immature technologies and faces a greater likelihood of

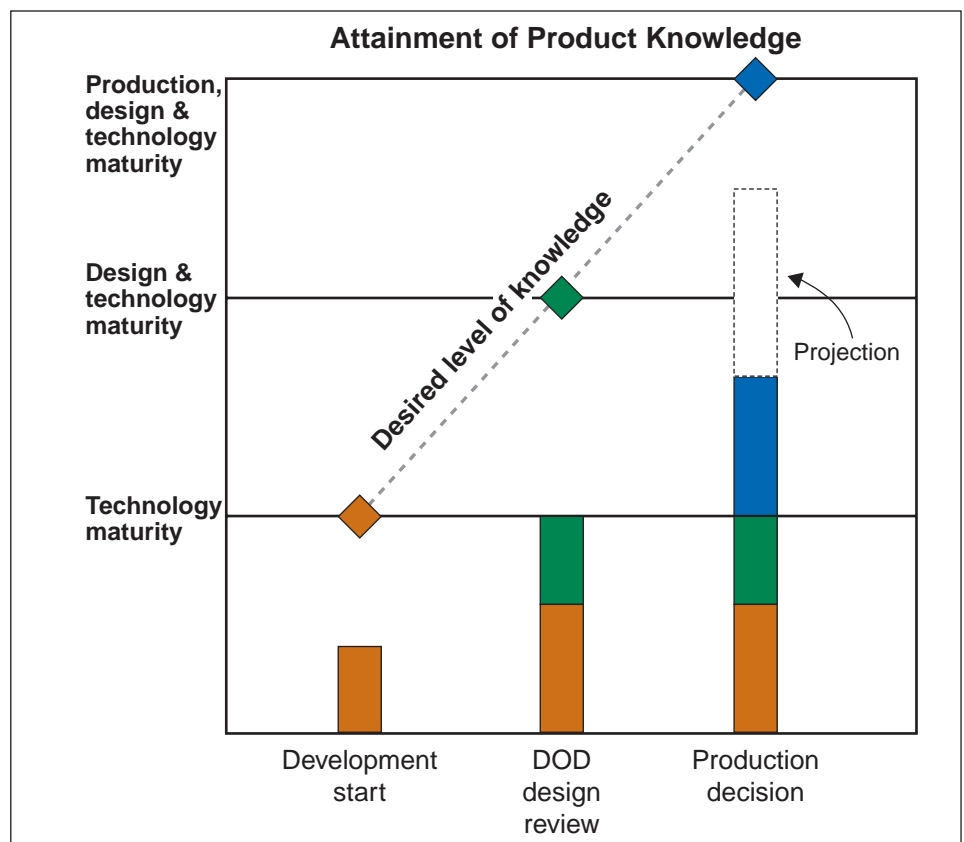
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<sup>17</sup> The nine programs are AMNS, B-2 RMP, C-130 AMP, CVN-21, DD(X), E-2 AHE, EA-18G, Excalibur, and WIN-T.

<sup>18</sup> The two programs are APKWS and ASDS.

cost and schedule increases as technology risks are discovered and resolved.

**Figure 4: Depiction of a Notional Weapon System's Knowledge as Compared with Best Practices**



Source: GAO.

An interpretation of this notional example would be that the system development began with key technologies immature, thereby missing knowledge point 1. Knowledge point 2 was not attained at the design review as some technologies were still not mature and only a small percentage of engineering drawings had been released. Projections for the production decision show that the program is expected to achieve greater levels of maturity but will still fall short. It is likely that this program would have had significant cost and schedule increases.

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We conducted our review from July 2004 through March 2005 in accordance with generally accepted government auditing standards. Appendix II contains detailed information on our methodology.

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## Assessments of Individual Programs

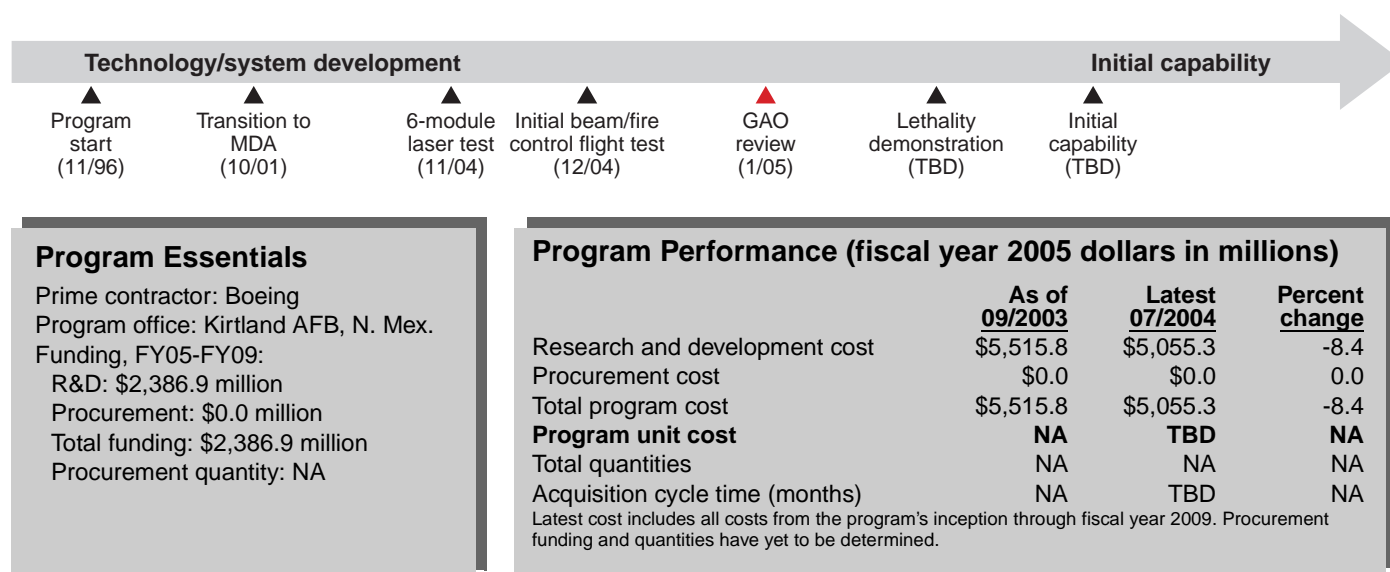
Our assessments of the 54 weapon systems follow.

## Airborne Laser (ABL)

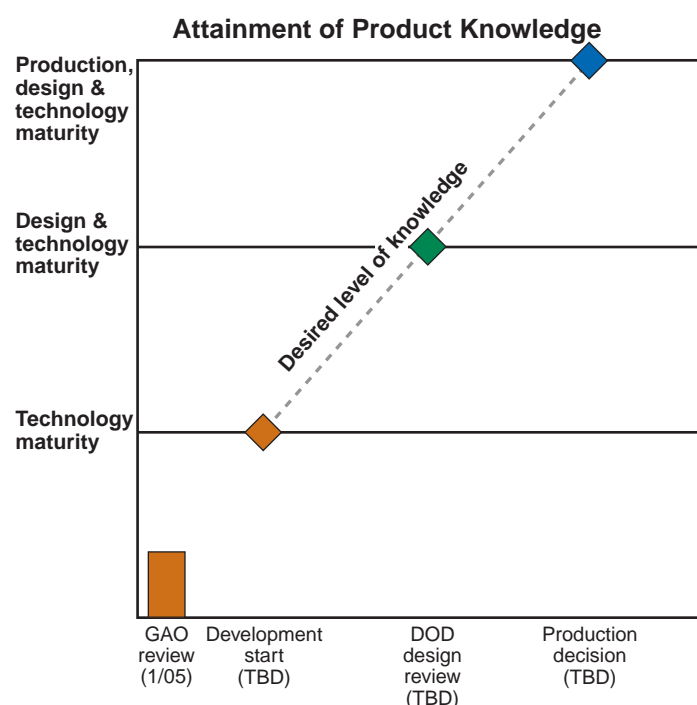
MDA's ABL element is being developed in incremental, capability-based blocks to destroy enemy missiles during the boost phase of their flight. Carried aboard a highly modified Boeing 747 aircraft, ABL employs a beam control/fire control subsystem to focus the beam on a target, a high-energy chemical laser to rupture the fuel tanks of enemy missiles, and a battle management subsystem to plan and execute engagements. We assessed the Block 2004 design that is under development and expected to lead to an initial capability in a future block.



Source: Airborne Laser Program Office.



Although program officials expected ABL to provide an initial capability during Block 2006, this event has been delayed and only one of its seven critical technologies is fully mature. During Block 2004, the program continues work on a prototype that is expected to provide the basic design for a future operational capability. Program officials expect to demonstrate the other six technologies during a prototype flight test that will assess ABL's lethality. Difficulty in integrating prototype components could delay this effort from 2005 to 2008. MDA has released about 94 percent of the engineering drawings for the prototype's design, which will be the basis for an initial operational capability during a future block if the test is successful. However, additional drawings may be needed if the design is enhanced or if problems encountered during flight testing force design changes.



## **ABL Program**

### **Technology Maturity**

Only one of ABL's seven critical technologies—managing the high-power beam—is fully mature. The program office assessed three technologies—the six-module laser, missile tracking, and atmospheric compensation—as nearly mature. The remaining three technologies—transmissive optics, optical coatings, and jitter control—are the least mature. According to program officials, all of these technologies are needed to provide the system with an initial operational capability.

While the program office has assessed the six-module laser as being close to reaching full maturity, the power generated by grouping six laser modules together must be demonstrated before full maturity can be reasonably assessed. The recent demonstration of the simultaneous firing of all six laser modules reduces risk in this area. Additional testing, planned over the next 6 months, must still be completed to demonstrate the full power and duration of the laser segment prior to installation on the aircraft.

The transmissive optics, optical coatings, and jitter control are the least mature critical technologies and consist of prototypes that have only been tested in the laboratory or demonstrated through analysis and simulation. The program plans to demonstrate all technologies in an operational environment during a flight test of the system prototype, referred to as lethal demonstration, in which ABL will attempt to shoot down a short-range ballistic missile. Challenges with integrating the laser and beam control/fire control subcomponents could delay this test into 2008, but the final schedule is to be determined. Upon successful completion of this test, MDA expects to develop a second aircraft that will provide an initial operational capability.

### **Design Stability**

We could not assess the design stability because ABL's initial capability will not be fully developed until the second aircraft—what is expected to provide an initial capability—is well underway. While the program has released 10,280 of the 10,910 engineering drawings for the prototype, it is unclear whether the design of the prototype aircraft can be relied upon as a good indicator of design stability for the second aircraft. More drawings may

be needed if the design is enhanced or if problems encountered during flight testing force design changes.

### **Production Maturity**

We did not assess the production maturity of ABL because MDA has not made a production decision. The program is producing a limited quantity of hardware for the system's prototype. Program officials explained that they continue to experience problems maintaining a stable manufacturing base for prototype subcomponents.

### **Other Program Issues**

Technological challenges caused the prime contract to approach its cost ceiling during fiscal year 2004. In early April 2004, MDA directed the ABL program to restructure the contract, increase its cost ceiling, and refocus the contractor's efforts on making technical progress. As a result, the cost ceiling was increased by \$1.5 billion and the period of performance was extended to 2008 from 2005. The contract is currently valued at approximately \$3.6 billion.

The focus of current work is on two near-term events. The first event was the six-module laser test in a ground test facility that the program completed in November 2004. The second event was the initial Beam Control/Fire Control flight test, which occurred in December 2004.

### **Agency Comments**

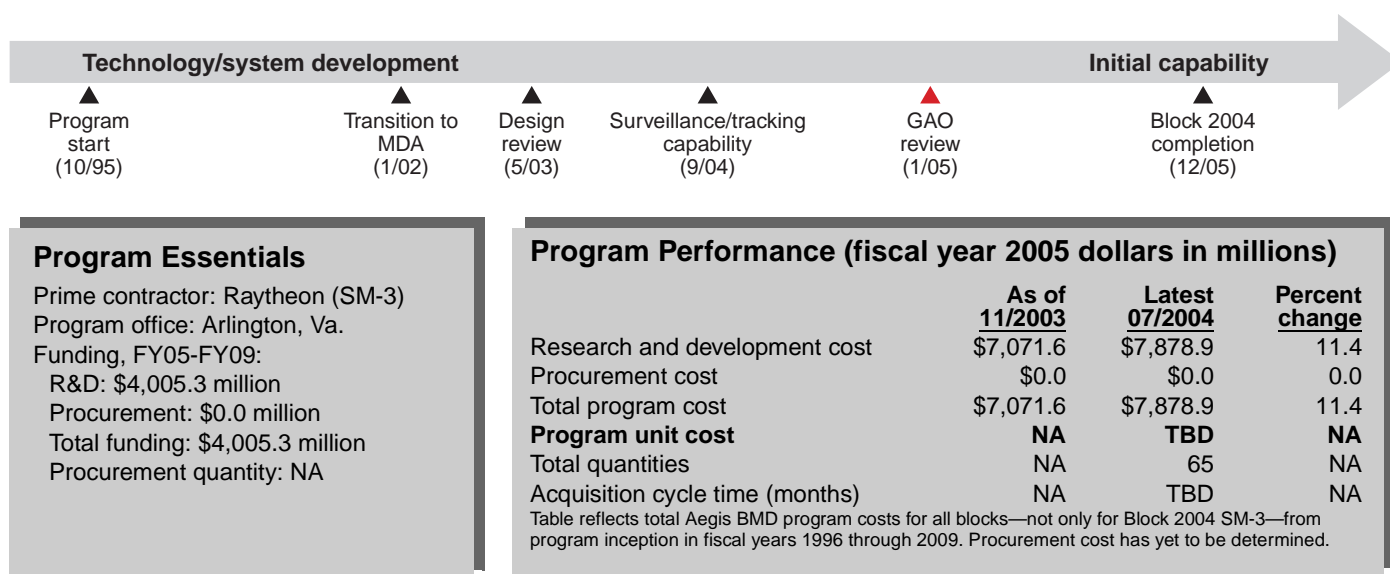
In commenting on a draft of this assessment, MDA maintained that the current design is stable despite the assessed technology maturity. Officials told us that because the ABL operational environment is impractical to duplicate on the ground, the technology maturity assessment will understate actual maturity until after 100 percent of the drawings are released. While the officials expect changes to future blocks as part of capability-based spiral acquisition, they believe the basic design will directly migrate to subsequent blocks.

## Aegis Ballistic Missile Defense (Aegis BMD)

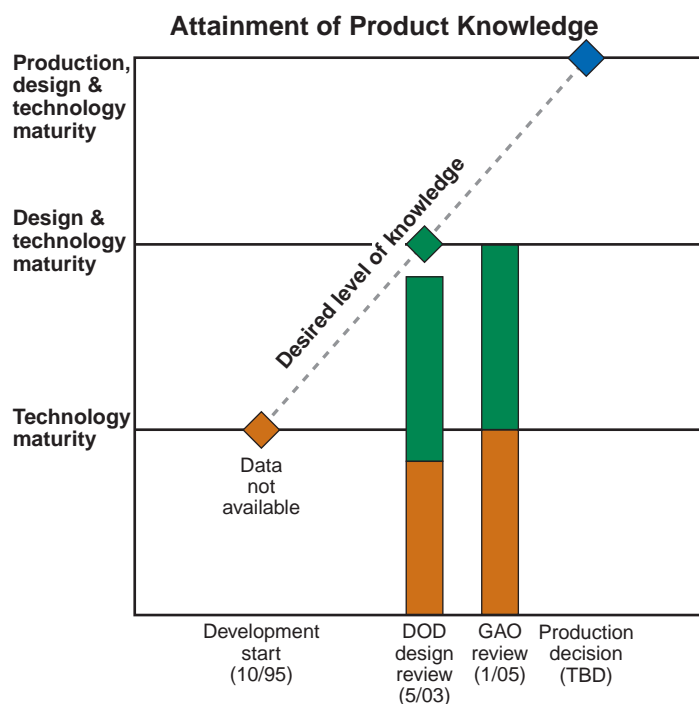
MDA's Aegis BMD element is a sea-based missile defense system being developed in incremental, capability-based blocks to protect deployed U.S. forces and critical assets from short- and medium-range ballistic missile attacks. Key components include the shipboard SPY-1 radar, hit-to-kill interceptors, and command and control systems. It will also be used as a forward-deployed sensor for surveillance and tracking of intercontinental ballistic missiles. We assessed only Block 2004 of the element's interceptor—the Standard Missile 3 (SM-3).



Source: Aegis BMD Program Directorate.



According to program officials, the first increment of SM-3 missiles being fielded during 2004-2005 has mature technologies and a stable design. However, the program has been struggling with the technology that maneuvers the missile's kinetic warhead (kill vehicle) to its target. Partial functionality of this "divert" technology was successful in 4 flight tests, but full functionality has only been demonstrated in ground tests—it failed during a June 2003 flight test. Design modifications were identified but will not be implemented in the first 8 missiles being fielded. Program officials noted that even with a reduced capability, these missiles provide a credible defense. All drawings for the first increment of missiles have been released to manufacturing. The program is not collecting statistical data on its production process but is using other means to gauge production readiness.



## **Aegis BMD Program**

### **Technology Maturity**

Program officials estimate that all three technologies critical to the SM-3 are mature. These technologies—the third stage rocket motor, the infrared seeker of the kinetic warhead, and the Solid Divert and Attitude Control System (SDACS) of the kinetic warhead—were all tested in flight. While the first two technologies were fully demonstrated in flight tests, the SDACS, which generates divert pulses to steer the kinetic warhead, was only partially demonstrated. As noted previously, full “divert” technology succeeded in ground testing but partially failed during a June 2003 flight test. According to program officials, the test failure was likely caused by a defective subcomponent within the SDACS, a problem that should be corrected through specific design modifications. Program officials note that only partial functionality of the SDACS is required for Block 2004, which was successfully demonstrated in flight tests. Although the kinetic warhead of these interceptors will have reduced divert capability, they provide a credible defense against a large population of the threat and can be retrofitted upon the completion of design updates and testing.

### **Design Stability**

Program officials reported that the design for the first eight interceptors being fielded during Block 2004 is stable with 100 percent of its drawings released to manufacturing. The program plans to implement design changes in subsequent configurations of the SM-3 (delivered during 2006-2007) to resolve the SDACS failure witnessed in the June 2003 flight test.

### **Production Maturity**

We did not assess the production maturity of the missiles being procured for Block 2004. Program officials stated that given the low quantity of missiles being produced, statistical process control data on the production process would have no significance. The Aegis BMD program is using other means to assess progress in production and manufacturing—such as integrated product teams, risk reviews, and SM-3 metrics—as part of its overall development of the SM-3.

### **Other Program Issues**

The Aegis BMD element builds upon the existing capabilities of Aegis-equipped Navy cruisers and destroyers. Planned hardware and software upgrades to these ships will enable them to carry out the ballistic missile defense mission. In particular, the program is working to upgrade Aegis destroyers for surveillance and tracking of intercontinental ballistic missiles. Because this function is new to the element—allowed only after the U.S. withdrawal from the Anti-Ballistic Missile Treaty—the program office faced a tight schedule to fully develop and test this added functionality, which it completed in September 2004 with the deployment of the first destroyer for this mission.

### **Agency Comments**

In commenting on a draft of this assessment, the program office stated that Aegis BMD progress remains on track. For example, the program deployed the first operational destroyers (for the long-range surveillance and tracking mission) to the Sea of Japan, delivered 5 missiles in November, and successfully ground tested the redesigned SDACS. It noted, however, that our review focused on the SM-3, a junior portion of the overall cost and development of the Aegis BMD system.

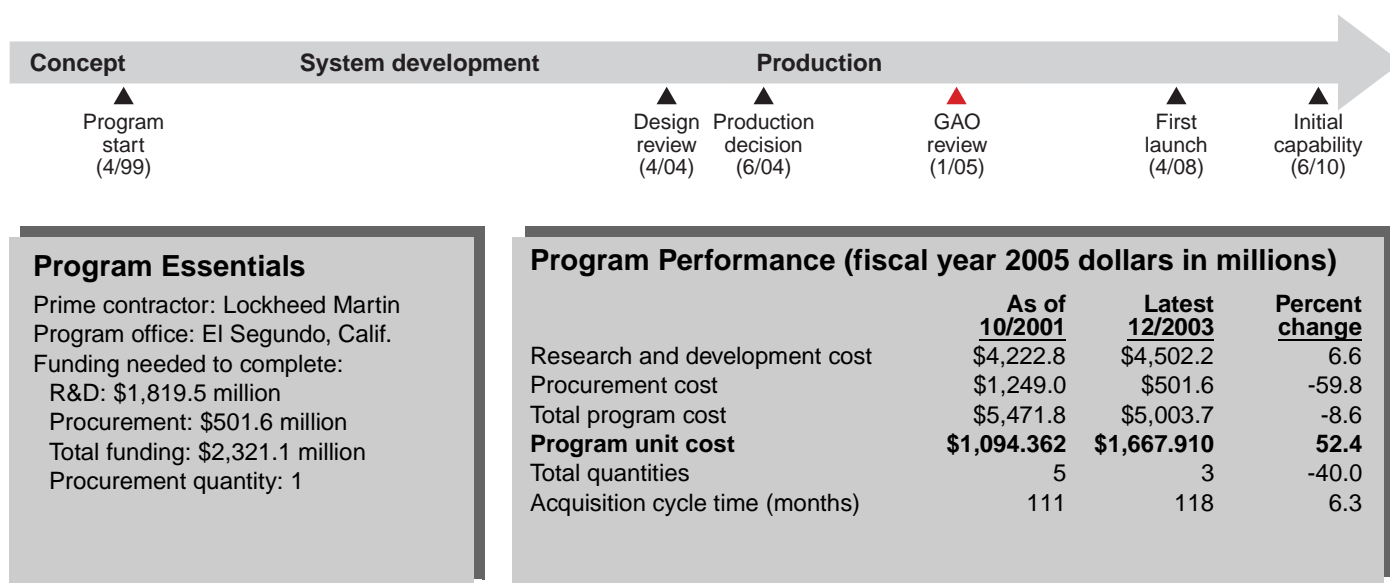
In addition, the program office reiterated that SDACS technology was successful in four of five Aegis BMD flight tests. The current SDACS configuration is fully capable of defeating the Block 2004 threat set, and a design update is in progress to complete the final increment of capability. As an application of capabilities-based acquisition, the warfighter is provided a significant capability years earlier (albeit using partial SDACS functionality) instead of waiting for a perfect design.

## Advanced Extremely High Frequency Satellites (AEHF)

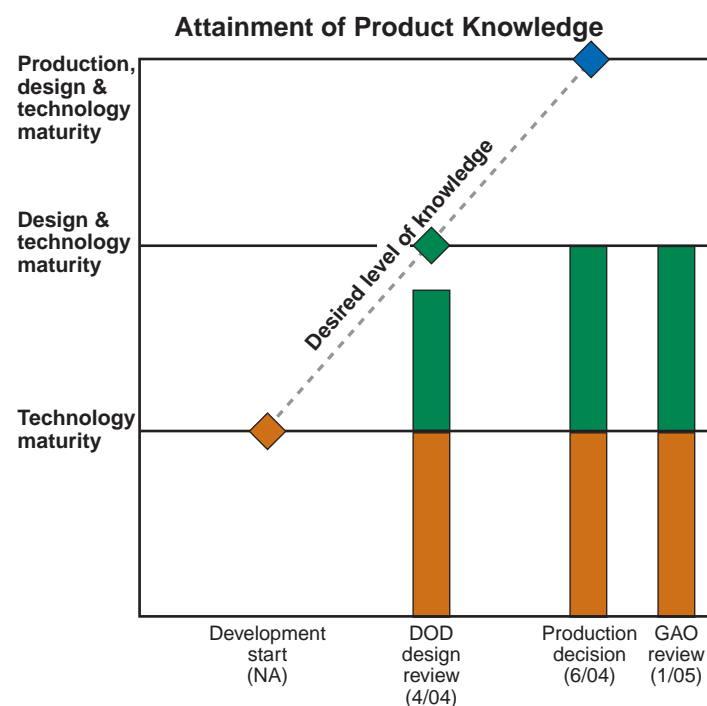
The Air Force's AEHF satellite system will replenish the existing Milstar system with higher capacity, survivable, jam-resistant, worldwide, secure communication capabilities for strategic and tactical warfighters. The program includes satellites and a mission control segment. Terminals used to transmit and receive communications are acquired separately by each service. AEHF is an international partnership program that includes Canada, United Kingdom, and the Netherlands. We assessed the satellite and mission control segments.



Source: Advanced EHF Program Office.



According to the program office, the AEHF program's technologies are mature and the design is stable. However, the high risk strategy of concurrently developing two critical path items has led to further schedule delays and cost increases. The program is relying on the concurrent development of the AEHF Comsec/Transec System (ACTS) suite of cryptological equipment, which limits access to authorized users, and terminals used for satellite command and control. Both of these items are being developed outside the program office. Delivery delays of the ACTS and command and control terminals resulted in an additional 12-month launch delay and an estimated 20 percent cost increase, incurring a Nunn-McCurdy breach (10 U.S.C. 2433) at the 15 percent threshold.



## **AEHF Program**

### **Technology Maturity**

All of the 14 critical technologies are mature, according to the program office. In addition, all 19 of the application-specific integrated circuits critical to functioning of the communications payload have been flight qualified through demonstration and testing.

### **Design Stability**

AEHF's design is now stable since more than 97 percent of the design drawings have been released. While the program completed its system level critical design review in April 2004 with only about two-thirds of the drawings released, the AEHF contractor has since resolved all outstanding issues from that review.

Production maturity could not be assessed as the program office does not collect statistical process control data. In June 2004, the formal decision was made to acquire the third and final satellite.

### **Other Program Issues**

The concurrent development of two critical path items—the ACTS and the command and control terminals—has led to further schedule delays and cost growth. The ACTS is a suite of cryptological equipment installed in both the satellite and the terminals to limit access to authorized users and is being developed and produced by the National Security Agency. The ACTS has already experienced significant cost growth and schedule delays due to production problems and changing security requirements. In September 2003, ACTS delivery delays and development problems led the program office to delay the launch of the first two satellites by 4 months. The second critical path item—the command post terminals—is developed and funded by another Air Force program office. These terminals must be in place and tested prior to the first launch or there will be a day-for-day slip in the satellite launch schedule.

The concurrent development of the AEHF satellites, terminals, and the ACTS has led to further delays and cost increases. Delayed delivery of the ACTS had resulted in an additional 12-month delay. Launches for the three AEHF satellites are now scheduled for April 2008, April 2009, and April 2010. The launch delays along with added payload

component testing and replacement of critical electronic parts are expected to increase the overall program cost by about 20 percent.

In December 2004, the Air Force notified Congress of a Nunn-McCurdy breach at the 15 percent threshold.

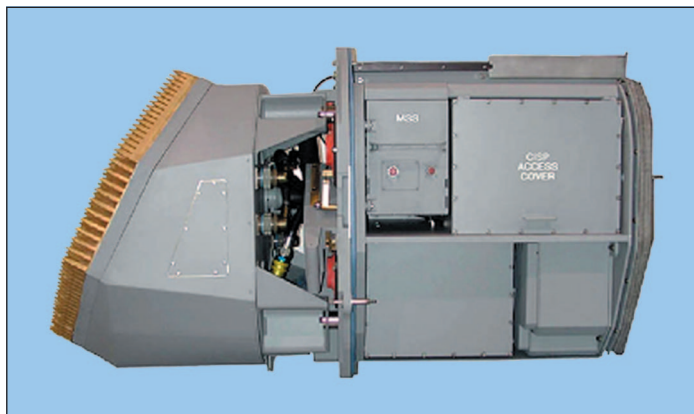
In December 2002, satellites four and five were deleted from the AEHF program because the new Transformational Satellite Communications System (TSAT), assessed elsewhere in this report, is to replace these satellites if they are sufficiently developed. The Air Force scheduled an interim review point in November 2004 to determine whether to buy additional AEHF satellites or rely on TSAT. However, in light of the 12-month program slip, the decision was delayed until November 2005.

### **Agency Comments**

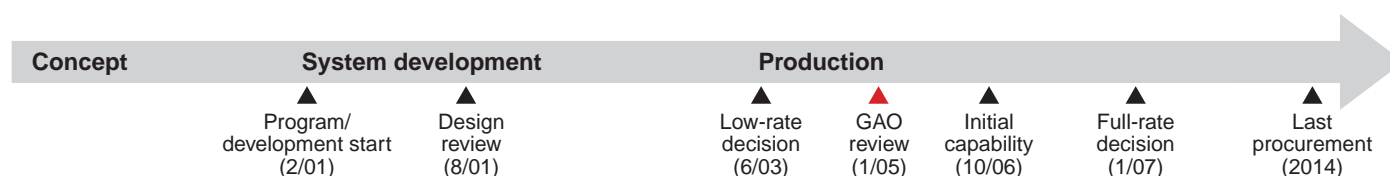
In commenting on a draft of this assessment, the Air Force provided technical comments, which were incorporated where appropriate.

## Active Electronically Scanned Array Radar (AESA)

The Navy's AESA radar is one of the top upgrades for the F/A-18E/F aircraft. It is to be the aircraft's primary search/track and weapon control radar and is designed to correct deficiencies in the current radar. According to the Navy, the AESA radar is key to maintaining the Navy's air-to-air fighting advantage and will improve the effectiveness of the air-to-ground weapons. When completed, the radar will be inserted in new production aircraft and retrofitted into lot 26 and above aircraft.



Source: U.S. Navy.



### Program Essentials

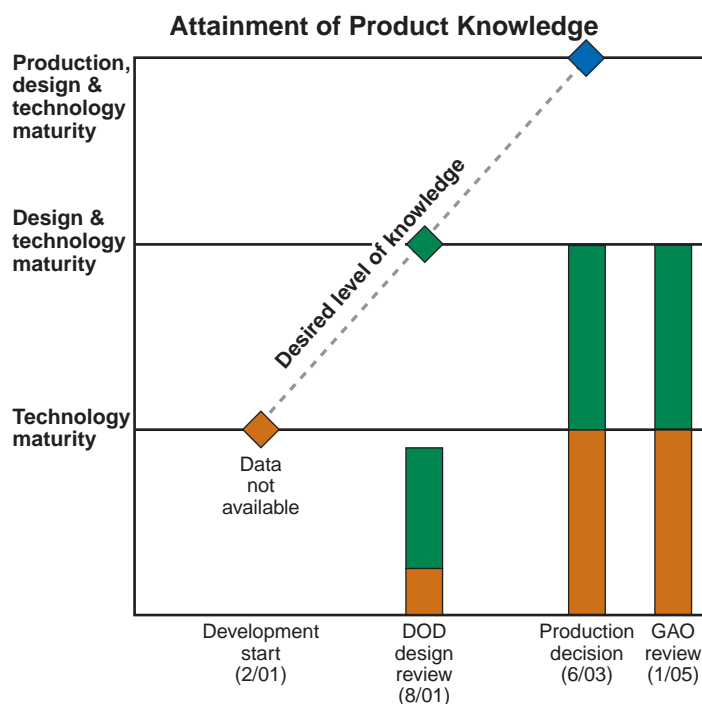
Prime contractor: McDonnell Douglas, Corp.  
 Program office: Patuxent River, Md.  
 Funding needed to complete:  
 R&D: \$165.3 million  
 Procurement: \$1,814.7 million  
 Total funding: \$1,980.0 million  
 Procurement quantity: 395

### Program Performance (fiscal year 2005 dollars in millions)

	As of 02/2001	Latest 12/2004	Percent change
Research and development cost	\$526.8	\$599.1	13.7
Procurement cost	\$1,690.2	\$2,029.2	20.1
Total program cost	\$2,217.0	\$2,628.3	18.6
<b>Program unit cost</b>	<b>\$5.342</b>	<b>\$6.333</b>	<b>18.6</b>
Total quantities	415	415	0.0
Acquisition cycle time (months)	69	68	-1.4

Procurement funding for the radar is included in the funding for the F/A-18E/F and EA-18G aircraft programs.

The AESA radar's critical technologies were not mature at the start of system development or at the design review, but they now appear to be mature. The design also appears stable. However, radar development is continuing during production. The program is tracking a number of risks with the technical performance of the radar. If problems are discovered, they could require design changes while the radar is in production. For example, the software schedule leaves little room for error or rework, and development of the radar simulation model puts training at risk. In addition, there are some production risks that could affect the quality of the initial radars and the aircraft delivery schedule. Antitamper protection for the radar is currently in design. The AESA program also has interdependencies with other programs that could make the radar vulnerable to delays in their progress.



## **AESA Program**

### **Technology Maturity**

The latest technology readiness assessment for the radar determined that the four critical technologies were mature. To further ensure technology maturity, a mini-technology assessment is planned prior to the full-rate production decision. By then, the technologies should have been demonstrated in their final form and under expected conditions.

### **Design Stability**

As of July 2004, all engineering drawings for the radar and its subsystems had been released. At the design review in 2001, 59 percent had been released. Development of the radar has continued during production. The program office has identified some development risks that could result in design changes. According to a program office risk assessment, the top current challenge involves the software. The lack of timely software delivery puts the program at significant risk, and could also require radar hardware rework due to delays in the flight test program. Another risk is that the radar simulation model integrated into the F/A-18 training simulator may not accurately represent the operation and performance of the radar, which could result in some training that is unrealistic. Further, the number of flight tests that can be conducted may not be adequate to mature radar software. Other current risks include whether the radar: will be able to track sufficient targets simultaneously; radiation emissions will interfere with F/A-18E/F weapon systems; and will have the capability to detect tail aspect targets at low altitude. Mitigation plans are in place to address all design risks.

### **Production Maturity**

During 4 low-rate production runs, 84 radars are planned—20 percent of the 415 radars to be procured. The program is currently in the second production run. Most radars are planned to be installed in F/A-18E/Fs on the aircraft production line. However, 135 radars will have to be retrofitted into already produced F/A-18E/Fs—a more costly process upfront, that, according to the Navy, is expected to save money on support costs later. We could not assess production maturity because statistical process control data are not being collected. Officials said they are comfortable with manufacturing processes based on audits and

inspections conducted at some key manufacturers. Nonetheless, radar production currently faces a number of risks. The radar contractor may have difficulty transitioning from development to production due to production risks, which could cause some late aircraft deliveries. Other risks include reliability problems with one of the radar's critical technologies may not allow initial radars to meet a specification and qualification tests may not be complete in time, resulting in delivering radar hardware that is not fully qualified. Moreover, full-rate production costs could increase significantly if the projected payoff from cost reduction initiatives is not fully realized. However, program officials expect significant savings from the cost reduction initiatives.

### **Other Program Issues**

The program office is closely tracking interdependencies that could place the radar at risk. Successful development of other Navy programs is required for the radar to meet key performance parameters. Also, the radar program is being developed, in part, with funding from contractors. Changes in the flow of this funding would affect the AESA program, but program officials stated that almost all of the contractor funding has been provided.

In 1999, DOD directed the services to implement antitamper protection to guard against exploitation of critical U.S. technologies. This protection was not one of the radar's original requirements. While officials said there is a requirement for this protection to have no effect on radar performance, operational tests of antitamper models are not planned until after operational tests of radars without this protection, which may identify problems that require design changes to the protection package.

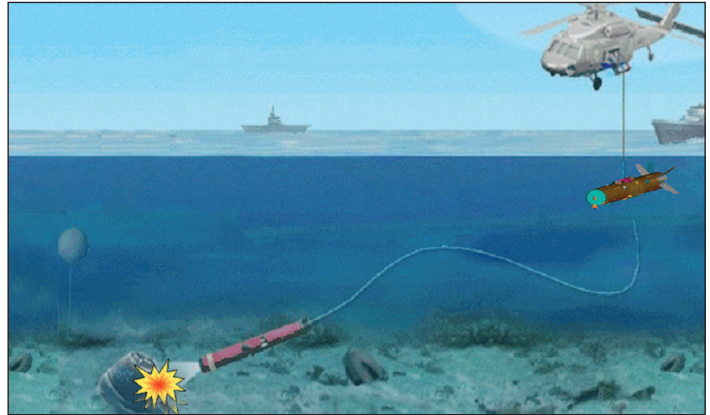
The program's strategy for a depot has changed. Plans have been canceled to stand up a Navy depot maintenance facility for the radar in 2010 at North Island, California. Instead, Raytheon will conduct depot maintenance at its facility in El Segundo, California, at substantial cost savings, according to program officials.

### **Agency Comments**

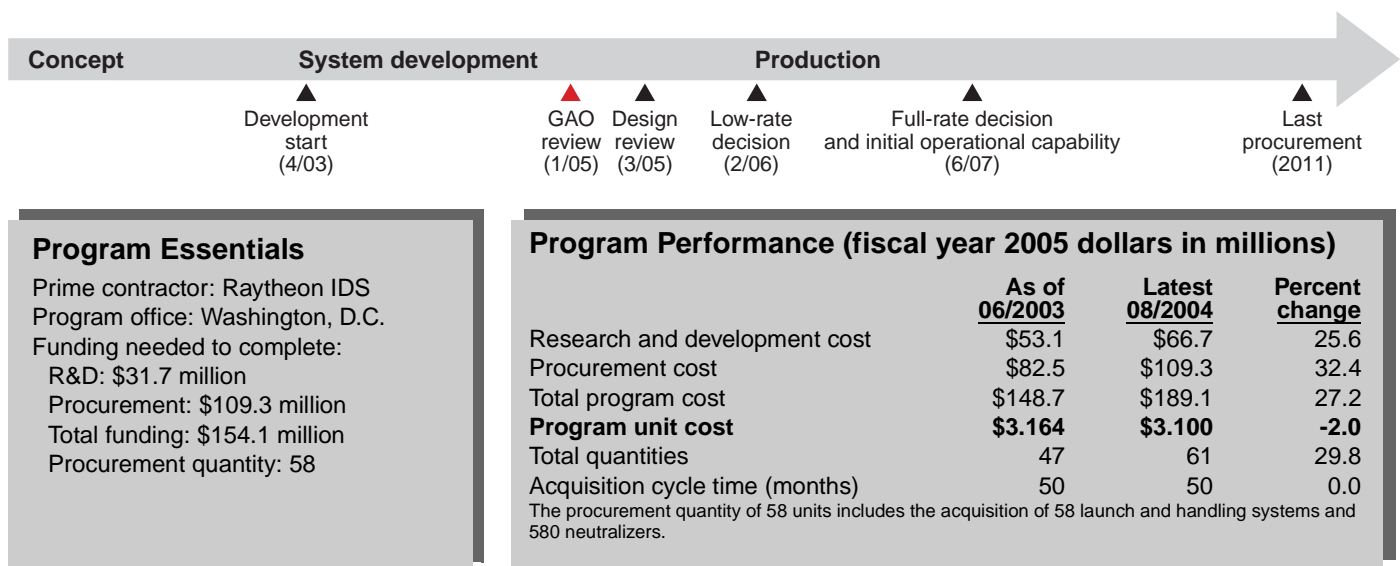
In commenting on a draft of this assessment, the Navy provided technical comments, which were incorporated as appropriate.

## Airborne Mine Neutralization System (AMNS)

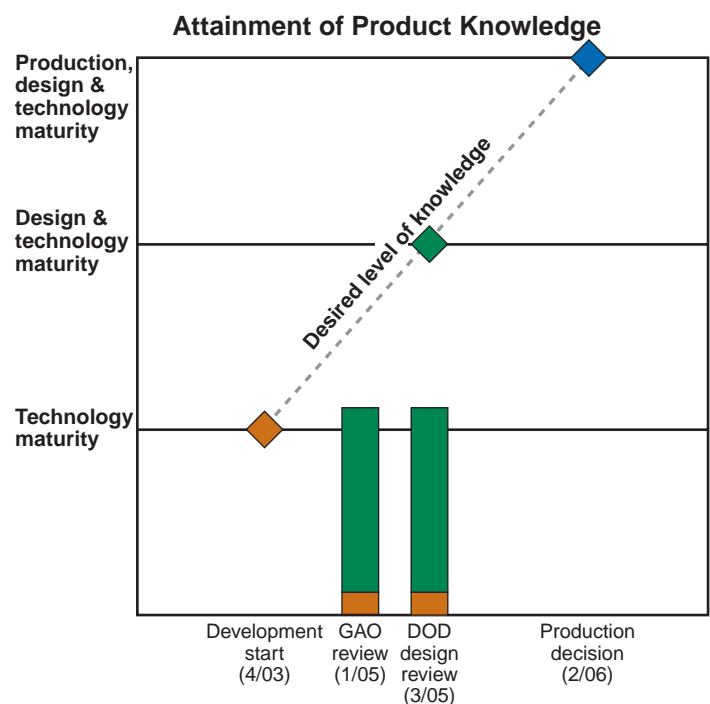
The Navy's AMNS is designed to relocate, identify, and neutralize bottom or moored sea mines. AMNS consists of an operating console and a launch and handling system containing up to four neutralizers. When deployed, the MH-60S helicopter hovers near the target mine and lowers AMNS via a tow cable into the water. A neutralizer, controlled through fiber-optic cable, exits the launch and handling system and uses sonar to find the mine and fires a lethal charge, destroying the mine and the neutralizer.



Source: U.S. Navy.



The AMNS program began system development with none of its four critical technologies mature. While progress has been made since then, program officials do not expect to achieve technology maturity until developmental tests are conducted in mid-2005. The AMNS program's design is stable, with approximately 90 percent of the drawings complete. However, since the AMNS technologies are not expected to demonstrate maturity until developmental testing is conducted, the program runs the risk that problems identified during that testing will require drawings to be modified. To maintain an initial operational capability of June 2007, the program office requested a \$13 million increase in research and development funds in order to support alternate testing on the MH-53E helicopter and to support delayed testing on the MH-60S helicopter.



## AMNS Program

### Technology Maturity

The AMNS launch and handling system, the deployment subassembly, the warhead assembly, and the neutralizer are not fully mature. The neutralizer, which was demonstrated in a relevant environment, is approaching full maturity. The program office describes the neutralizer as a nondevelopmental item because it is already operational. However, it needs to undergo safety and performance improvements before it will be ready for AMNS. The other three technologies have not been integrated or demonstrated outside of a laboratory environment, but program officials have stated that no technology hurdles remain, merely engineering challenges. Program officials expect all four technologies to demonstrate maturity during developmental testing that is scheduled to take place between May and October 2005.

Among risks identified by program officials are concerns that the neutralizer will not launch properly in an environment of strong water currents. The program office is attempting to mitigate this risk by establishing plans and funding for testing the neutralizer in strong water currents, including flume tank testing. Additionally, program officials noted concerns about the survivability of the launch and handling system in an underwater explosives environment. The program office plans for this risk to be mitigated through an analysis of launch and handling system internal parts and an analysis to prove that the launch and handling system can tolerate environments of up to 50G levels.

### Design Stability

Approximately 90 percent of the AMNS drawings are currently releasable. Moreover, the program office projects all drawings to be releasable to manufacturing at the completion of the design readiness review in March 2005. According to program officials, top level assembly drawings will be considered at the design readiness review. Detailed designs of AMNS components were validated through 17 interim design reviews held by the program office.

Because the AMNS technologies are not expected to demonstrate maturity until developmental testing is conducted in mid-2005, the program runs the risk that any problems identified during testing would require drawings to be modified.

### Other Program Issues

The program office has requested an approximately \$13 million increase in research and development funds for the fiscal year 2006 budget. According to program officials, this increase is required to support alternate testing on the MH-53E helicopter and to support a 16-month delay in completion of testing on the MH-60S helicopter. The MH-60S helicopter will not be available to support the current AMNS development and test schedule. Without alternate testing on the MH-53E helicopter, the program will not be able to make a low-rate initial production decision in February 2006 or, more importantly, maintain an initial operational capability of June 2007. For the MH-60S helicopter, development testing is not scheduled to start until 6 months after a low-rate initial production decision has been made.

### Agency Comments

In commenting on a draft of this assessment, the Navy stated that the program quantity increased from 47 to 61 as a result of a change in Navy strategy to deploy the system from Littoral Combat Ships rather than aircraft carriers. Regarding technology maturity, it noted that currently the program's critical technologies, for example the warhead assembly, are slightly more mature than indicated in the assessment. In addition to performing an analysis to prove that the launch and handling system can tolerate high-pressure underwater environments, the Navy intends to conduct Underwater Explosive Testing as further risk mitigation.

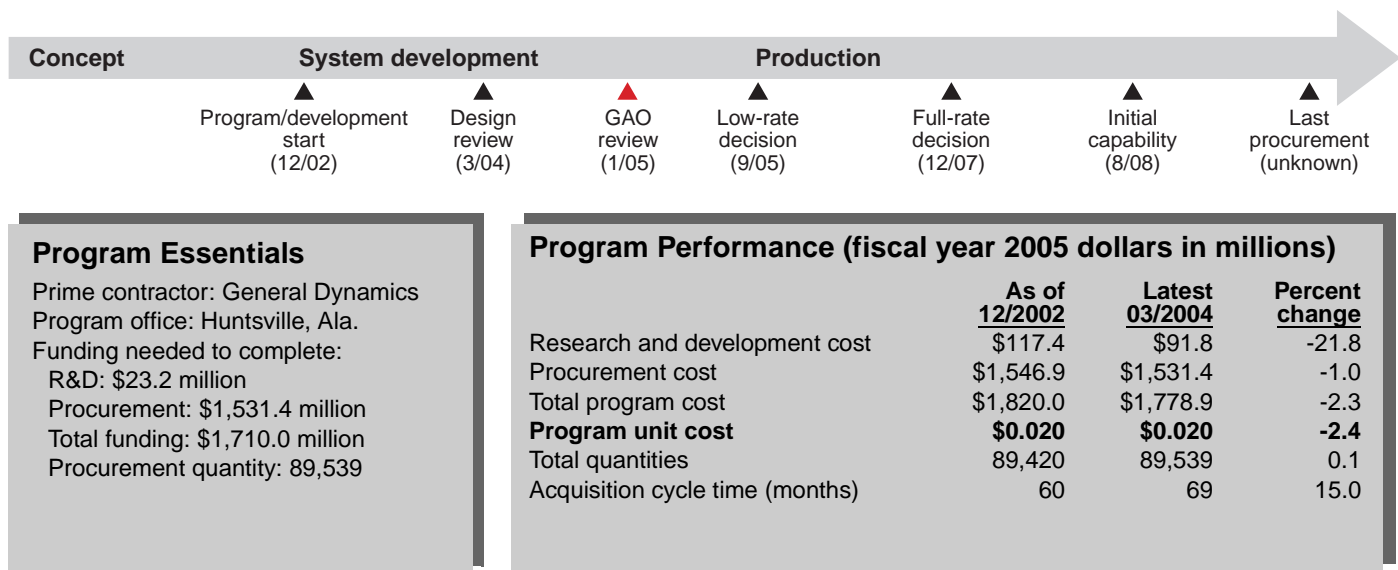
Regarding other program issues, the Navy stated that while alternate platform testing on the MH-53E helicopter would enable the program to meet its low-rate initial production decision and initial operational capability targets, alternate platform testing is pending approval by the Assistant Secretary of the Navy (Research, Development, and Acquisition). It also indicated that constraints in the availability of MH-60S test assets have the potential to delay the program's schedule and increase its cost beyond the projections presented in the assessment.

## Advanced Precision Kill Weapon System (APKWS)

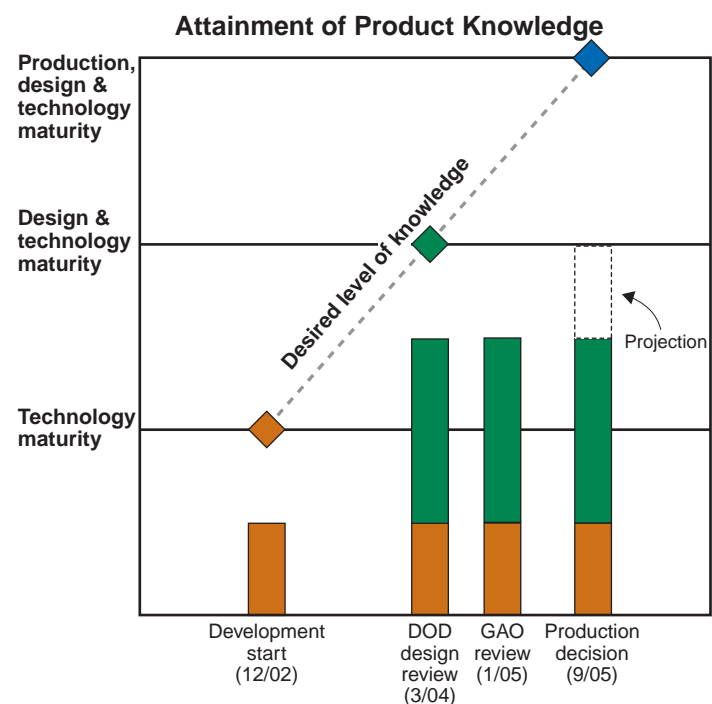
The Army's APKWS is a precision-guided, air-to-surface missile designed to engage soft and lightly armored targets. The system will add a new laser-based seeker to the existing Hydra 70 Rocket System and is expected to provide a lower cost, accurate alternative to the Hellfire missile. Future block upgrades are planned to improve system effectiveness. We assessed the laser guidance technology used in the new seeker.



Source: © 2003 General Dynamics Armament and Technical Products, All Rights Reserved.



The APKWS entered system development and held its design review before demonstrating that its critical guidance technology was fully mature. While the system's design was otherwise stable at the time of the March 2004 design review, initial system-level testing identified problems with the design. Program plans call for a production decision in September 2005 and low-rate production contract award in December 2005. We were unable to assess the program's production maturity because program officials do not expect to begin collecting statistical data on their key manufacturing processes until the start of production. Remaining efforts include completing developmental and operational testing. If subsequent testing identifies further problems with the design, additional costs of redesign and modification of drawings late in development could be incurred.



## **APKWS Program**

### **Technology Maturity**

The APKWS program has not demonstrated full maturity of its only critical technology—laser guidance. Although a prototype guidance system was successfully demonstrated under the Low Cost Precision Kill Advanced Technology Demonstration, the current design for the guidance system includes numerous hardware changes to improve system cost, performance, and producibility. The new guidance system will not be fully integrated and tested from an aircraft until winter 2005. Program officials noted that although the prototype system design exists, reverting to it would increase cost and degrade the system's performance and producibility.

### **Design Stability**

Program officials released 100 percent of the drawings after a system-level design review in March 2004. Recently completed testing, however, uncovered the need for design changes. The APKWS, to date, has completed two test flights. The first test flight went as planned. The second flight test missile, however, experienced a mechanical failure of the wing lock mechanism, causing the test missile to veer off target. The program office identified a design solution, and flight testing resumed in September 2004.

### **Production Maturity**

Program officials expect that there will be nine key processes associated with manufacturing the APKWS. The program plans to collect statistical data on these processes when production begins in fiscal year 2006.

### **Other Program Issues**

According to program officials, the Army cut APKWS research, development, test, and evaluation (RDT&E) funding by 22.1 percent due to other funding priorities. These officials noted that this reduction affects planned improvements to the warhead, fuze, seeker, and propulsion subsystems. Furthermore, the program has experienced a 15.3 percent growth in acquisition cycle time as the result of slower initial production of the system than originally planned.

### **Agency Comments**

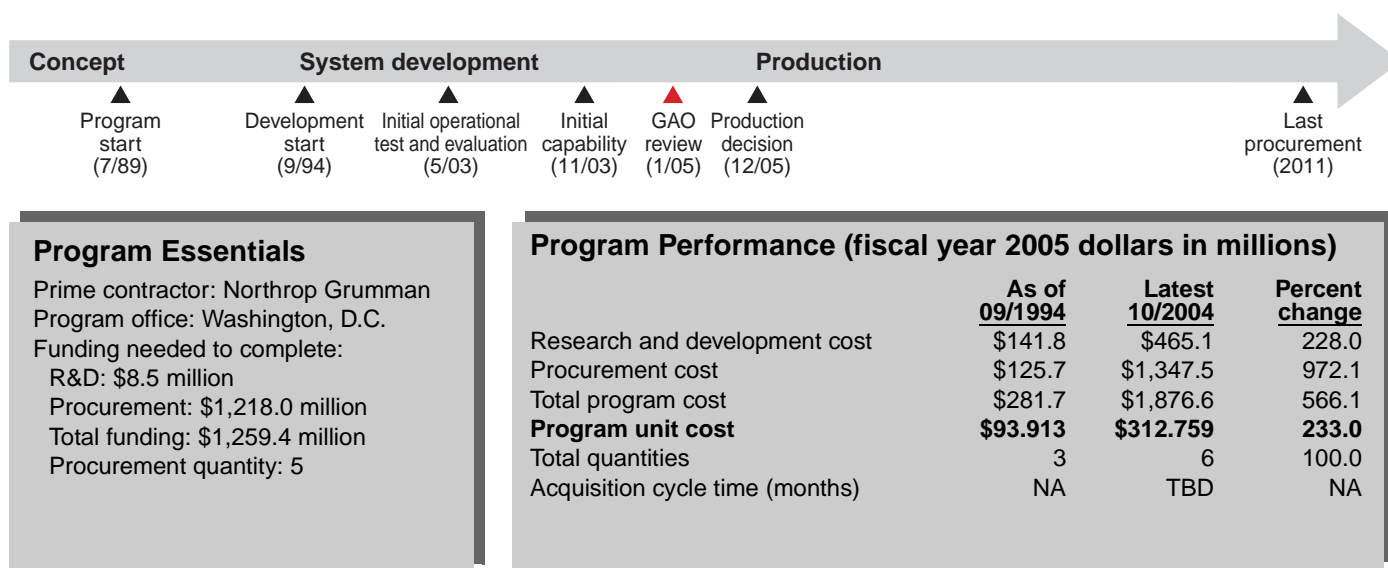
In commenting on a draft of this assessment, the Army concurred with this assessment.

## Advanced SEAL Delivery System (ASDS)

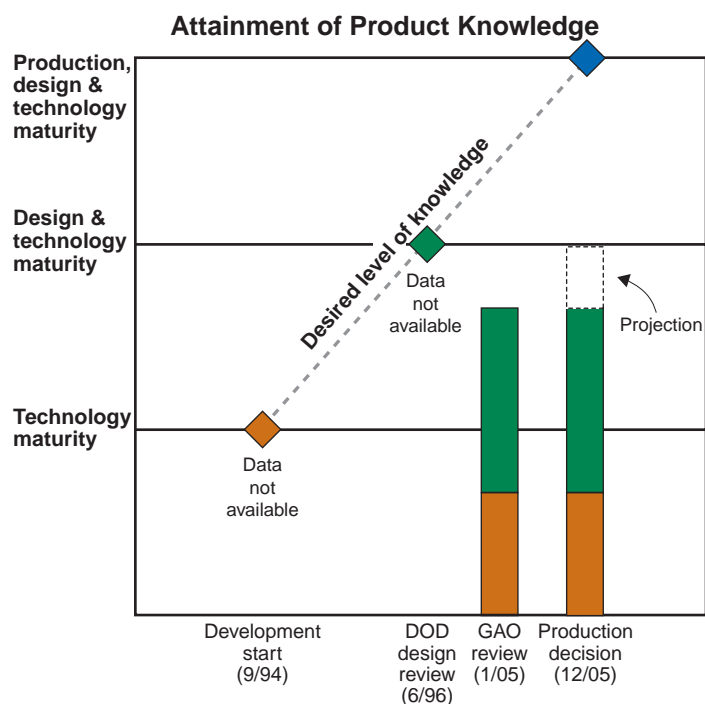
The Special Operations Forces' ASDS is a battery-powered, dry interior minisubmarine developed for clandestine insertion and extraction of Navy SEALs and their equipment. It is carried to its deployment area by a specially configured SSN-688 class submarine. It is intended to provide increased range, payload, on-station loiter time, and endurance over current submersibles. The 65-foot long, 8-foot diameter ASDS is operated by a two-person crew and equipped with a lock out/lock in chamber to allow divers to exit and reenter the vehicle.



Source: U.S. Navy.



One of ASDS's three critical technologies—the lithium ion battery—has not reached maturity, and the first boat has required some design changes. The production decision has been delayed from June 2004 until December 2005 to allow time to produce and test a new battery and develop and test other vehicle design changes. The Navy selected a design for the lithium ion battery and, in May 2004, it awarded a contract to develop a full shipset unit for ASDS. Battery production will take about 1 year, and at-sea demonstration is expected in fiscal year 2005. Concurrent with battery replacement, other vehicle improvements are being developed and tested and design problems are being addressed. Acoustic signature issues are being addressed; however, this requirement does not have to be met until delivery of the second ASDS boat.



## **ASDS Program**

### **Technology Maturity**

Of the three critical technologies identified by the ASDS program office, one—the lithium ion battery—has not reached maturity. However, it is expected to be mature before the December 2005 production decision for additional boats.

Acoustic, or noise level, problems are being addressed; however, the first boat is not quiet enough to meet acoustic stealth requirements. In earlier tests, the ASDS propeller was the source of the most significant noise, and a new composite propeller was installed before operational test and evaluation in 2003. Although program officials believe it meets requirements, precise acoustic measurements have not been made and are not scheduled to be done before the production decision. Other acoustic issues will be addressed on a time-phased basis because the acoustic requirement has been deferred until delivery of the second boat.

### **Design Stability**

Although all engineering drawings for ASDS have been released to manufacturing, ASDS design changes have been required based on additional improvements, test results, and other issues since ASDS reached initial operational capability in November 2003. An assessment of ASDS survivability design features is also underway; however, the Vulnerability Assessment Report will not be completed until April 2005.

An updated ASDS operational requirements document was approved in June 2004. The number of key performance parameters (those elements that are so significant that a failure to meet them could call into question a system's ability to perform missions) were reduced from 16 to 8, and they include one new requirement (operational availability). Other requirements are categorized as system critical requirements.

Until all requirements are addressed, technical problems are solved, and testing is completed, we believe ASDS's final design will remain uncertain and may have cost and schedule implications.

### **Other Program Issues**

The Navy completed an independent cost estimate, including life-cycle costs, in March 2004. However, data were not released, and the estimates are now out-of-date because they do not reflect the impact of the 2-year delay in production of the second boat. According to the June 2004 Selected Acquisition Report, the U.S. Special Operations Command was preparing a new proposed program plan to account for the delay in the production decision and updated cost information was expected to be reported in the December 2004 report. However, according to the Navy's January 2005 update, the revised program plan and updated cost estimate will be developed, reviewed, and approved as part of the production decision, which has been delayed until December 2005. Since the program's first cost estimate was originally approved in 1994, research and development costs have more than tripled.

The Navy plans to conduct follow-on testing to verify that deficiencies and vulnerabilities identified during the May 2003 operational evaluation are corrected. However, not all results will be known before the scheduled production decision.

### **Agency Comments**

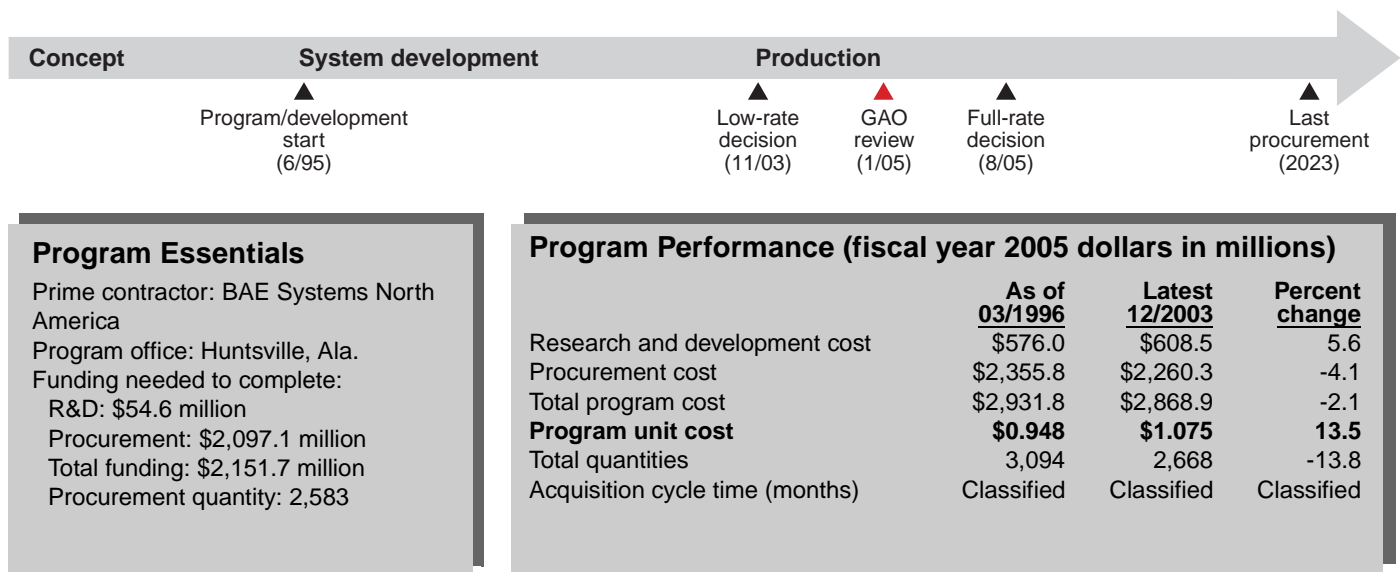
The Navy provided technical comments, which were incorporated as appropriate.

## Advanced Threat Infrared Countermeasure/Common Missile Warning System

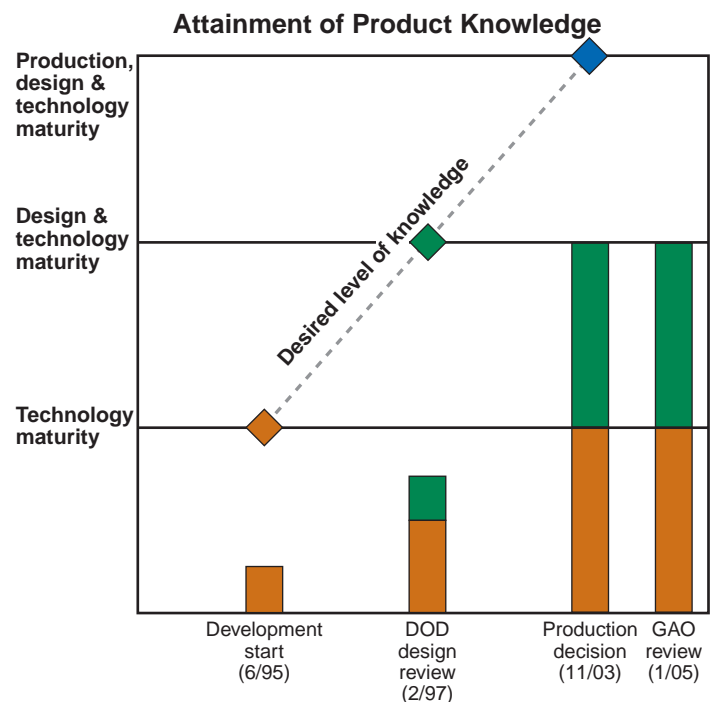
The Army's and the Special Operations Command's ATIRCM/CMWS is a component of the integrated infrared countermeasures suite planned to defend U.S. aircraft from advanced infrared guided missiles. The system will be employed on Army and Special Operations aircraft. The system includes an active infrared jammer, a missile warning system, and a countermeasure dispenser capable of loading and employing expendables, such as flares, chaff, and smoke.



Source: BAE Systems.



The ATIRCM/CMWS program entered production in November 2003 with technologies mature and designs stable. Currently, the program's production processes are at various levels of control. The CMWS portion of the program entered limited production in February 2002 to meet urgent deployment requirements. However, full-rate production for both components was delayed because of reliability problems. Over the past several years, the program has had to overcome cost and schedule problems brought on by shortfalls in knowledge: key technologies were demonstrated late in development and only a small number of design drawings were completed by design review. At the low-rate production decision point, the Army developed a new cost estimate reducing program procurement cost substantially.



## **ATIRCM/CMWS Program**

### **Technology Maturity**

The ATIRCM/CMWS's five critical technologies are mature. However, they did not mature until after the design review in February 1997. Most of the early technology development effort was focused on the application to rotary wing aircraft. When system development began in 1995, the requirements were expanded to include Navy and Air Force fixed wing aircraft. This change caused problems that largely contributed to cost increases of more than 150 percent to the development contract. The Navy and the Air Force subsequently dropped out of the program, rendering the extra effort needless, but the Navy and the Army are currently pursuing future joint production planning.

### **Design Stability**

The basic design of the system is complete with 100 percent of the drawings released to manufacturing. The design was not stable at the time of the design review, with only 22 percent of the drawings complete. This was primarily due to the expanded requirements. It was not until 2 years after the design review that 90 percent of the drawings were released and the design was considered stable. This resulted in inefficient manufacturing, rework, additional testing, and a 3-year schedule delay. The system design was successfully demonstrated through engineering and manufacturing development and transitioned to production.

### **Production Maturity**

The production maturity could not be assessed based on the information provided by the program office. According to program officials, the ATIRCM/CMWS program has 16 key manufacturing processes in various phases of control. They stated that ATIRCM statistical process controls are in development, control plans are being enhanced and as the program continues in production and data are gathered, lessons learned will be included in the processes. The Army entered limited CMWS production in February 2002 to meet an urgent need of the U.S. Special Operations Command. Subsequently, full-rate production was delayed for both components due to reliability testing failures. The program implemented reliability fixes to six production representative subsystems that will be used for initial operational test and evaluation.

These systems were delivered in March 2004. The full-rate production decision for the complete system is now scheduled for 2006.

### **Other Program Issues**

The Army procured an initial 32 systems in fiscal year 2002 for use on the U.S. Special Operations Command's CH-47 helicopters. The Army plans to procure a total of 99 systems to outfit special operations aircraft between fiscal year 2003 and 2009. Currently, program officials are working to integrate CMWS on 16 additional platform types and models, which will result in an increase in quantity and funding. The CMWS low-rate initial production quantity increased by 141 systems to a total of 200. The Army procured all 200 of these systems, and deliveries are on schedule.

At the low-rate production decision point, the Army developed a new cost estimate for the program that featured a variety of different program assumptions. For example, program officials deleted 17 years of Contractor Logistics Support, reducing potential duplication, and deleted 29 training systems. As a result, program officials report that procurement cost was reduced by 17 percent.

### **Agency Comments**

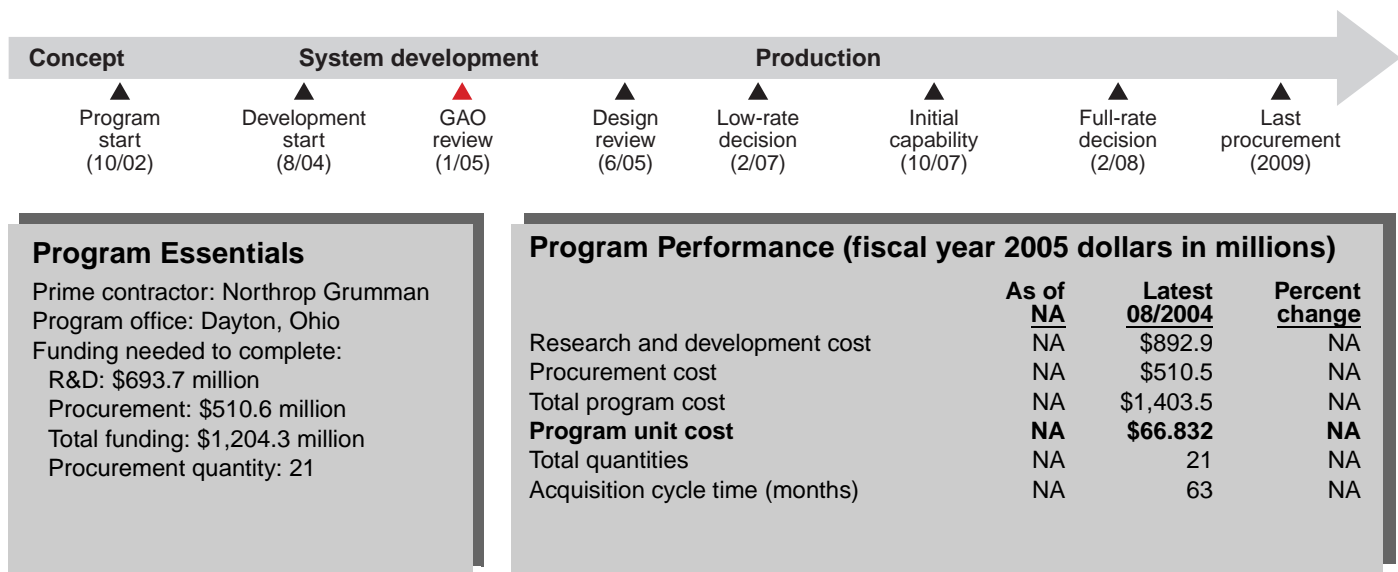
The Army concurred with this assessment and provided technical comments, which were incorporated where appropriate. Additionally, the Army commented that in January 2004, it directed the acceleration of CMWS for deployment on Operation Iraqi Freedom aircraft. Initial operational tests and evaluation will be completed during fiscal year 2005 for CMWS and in fiscal year 2006 for ATIRCM.

## B-2 Radar Modernization Program (B-2 RMP)

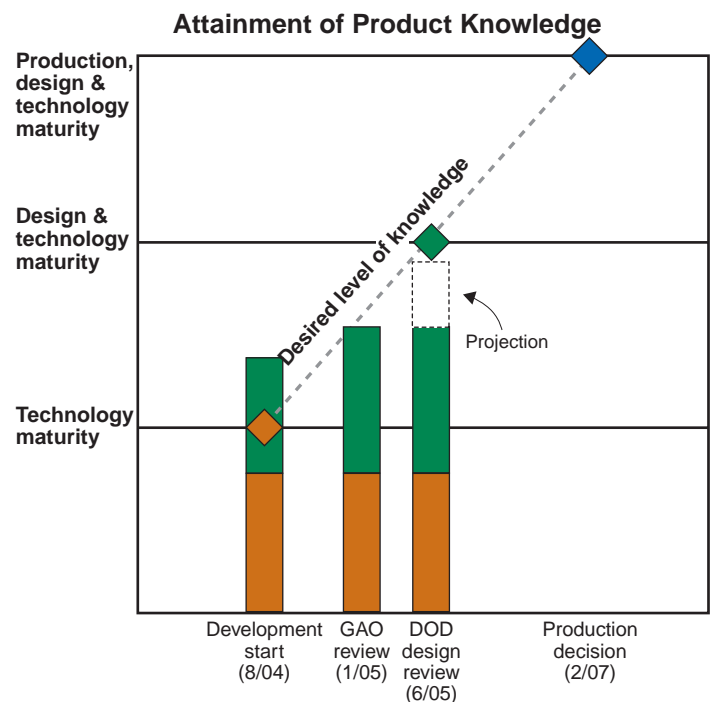
The Air Force's B-2 RMP is designed to modify the current radar system to resolve potential conflicts in frequency band usage. To comply with federal requirements, the frequency must be changed to a band where the B-2 will be designated as a primary user. The modified radar system is being designed to support the B-2 stealth bomber and its combination of stealth, range, payload, and near precision weapons delivery capabilities.



Source: U.S. Air Force, U.S. Edwards Air Force Base, California.



The B-2 RMP entered system development in August 2004 with two critical technologies mature and two approaching maturity. All critical technologies are planned to be mature by the June 2005 design review. The program has released 71 percent of its design drawings and plans to have 85 to 95 percent released by the June 2005 design review. Program officials indicated that production maturity metrics will be formulated during development and that these metrics may or may not include manufacturing process control data. The program plans to build six radar units during development for pilot training with the B-2 operational wing prior to the planned completion of flight testing. Even though these units are necessary, building them early in development adds to the risk of later design changes because most of the radar flight-test activity will not occur until after these units are built.



## **B-2 RMP Program**

### **Technology Maturity**

The B-2 RMP entered development in August 2004 with two of four critical technologies mature and two others approaching maturity. Last year the program reported having two critical technologies, but a formal technology readiness assessment conducted in February 2004 concluded that two additional technologies should be considered critical. The additional two technologies, the receiver/exciter for the electronic driver cards and aspects of the antenna designed to help keep the B-2's radar signature low, are not considered fully mature but are approaching maturity. There are no backup technologies for two technologies approaching maturity, but both completed their design phases in April 2004 and the program office estimates that both will be fully mature by the final design review in June 2005.

### **Design Stability**

The program has completed and released 71 percent of its engineering drawings to manufacturing. The program office has scheduled the design readiness review for June 2005 and plans to have 85 to 95 percent of its drawings released by that time. The program, however, does not use the release of design drawings as a measure of design maturity but instead uses the successful completion of design events, such as subsystem design reviews, as its primary measure of design maturity.

### **Production Maturity**

Production maturity metrics are planned to be formulated during development. These metrics, which may or may not include manufacturing process control data, are planned to be used as measures of progress toward production maturity during a production readiness review prior to the start of production in February 2007. The program is also involved in a proof-of-manufacturing effort to demonstrate that the transmit/receive modules can be built to specifications.

### **Other Program Issues**

The program plans to build six radar units during development and later modify these units for placement on operational B-2 aircraft. The Air Force needs these radar units available when the current B-2 radar frequency becomes unavailable, in order to continue air crew training and proficiency

operations. Even though these units are necessary, building them early in development adds risk because most of the radar flight-test activity will not occur until after these units are built.

### **Agency Comments**

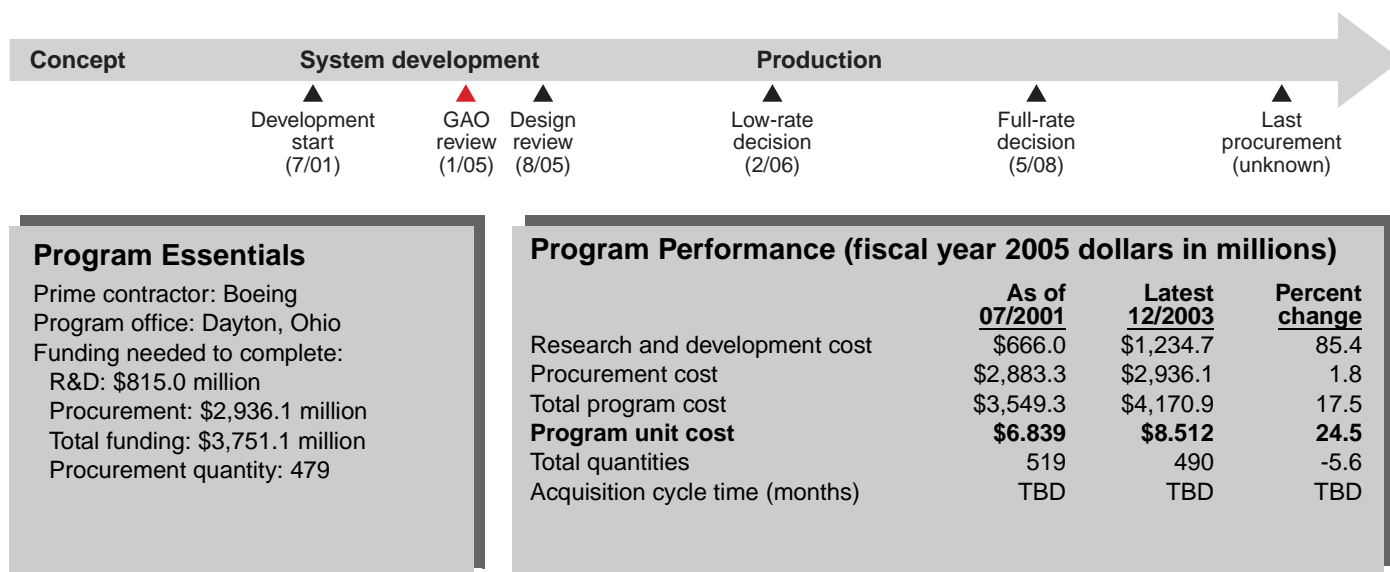
The Air Force concurred with this assessment. It commented that the program recognizes a level of risk associated with building the six development units prior to formal testing in order to satisfy a critical schedule constraint. It stated that, as a result, the program office has placed a heavy emphasis on risk reduction and that the program is progressing well thus far in system development. It further commented that it is important to note that these six development units are also planned to be used for collection of field level reliability and maintainability data. It also noted that the program has successfully completed its proof-of-manufacturing effort for the transmit/receive modules, has now delivered over 600 modules, and has completed and released approximately 70 percent of its engineering drawings.

## C-130 Avionics Modernization Program (C-130 AMP)

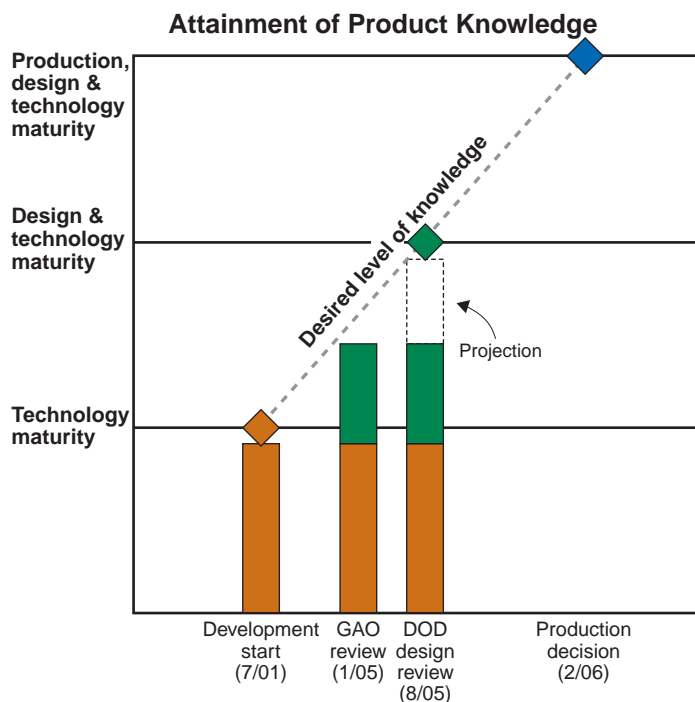
The Air Force's C-130 AMP standardizes the cockpit configurations and avionics for 14 different mission designs of the C-130 fleet. It consolidates and installs the mandated DOD Navigation/Safety modifications, the Global Air Traffic Management systems, and the C-130 broad area review requirements. It also incorporates other reliability, maintainability, and sustainability upgrades and provides increased situational awareness capabilities and reduces susceptibility of Special Operations aircraft to detection/interception.



Source: C-130 Avionics Modernization Program, System Program Office.



The C-130 AMP is using primarily commercial and modified off-the-shelf technologies, and it entered system development with all but one of its six critical technologies mature. The remaining technology is nearing full maturity; however, there is concern that it may not meet current performance requirements. Program officials reached agreement with the user to field a lesser set of requirements equivalent to the current capability in fiscal year 2008. Program officials plan to release 90 percent of engineering drawings by the design review and have made progress toward that goal. Currently, 48 percent of the engineering drawings are releasable compared to 14 percent a year ago. Additionally, the program office recently modified the contract to accelerate the installation on Special Operations aircraft by 1 year, placing additional pressure on the already compressed schedule.



## C-130 AMP Program

### Technology Maturity

Five of the C-130 AMP's six critical technologies are fully mature, as the program is primarily utilizing proven commercial and modified off-the-shelf technology for all AMP capabilities. The remaining critical technology, the Terrain Following and Terrain Avoidance (TF/TA) capability, was demonstrated through the Air Force Research Lab's Quiet Knight advanced technology demonstration program and is nearing full maturity. There is a risk, however, that the TF/TA technology may not meet a key requirement to operate at 250 feet. Program officials worked with the user to agree on initially fielding TF/TA capability between 250 and 1,000 feet, which is the current capability of the technology. Program officials plan to determine through analysis the residual capability of the TF/TA technology to fly lower. However, if such capability cannot be achieved, redesign may be necessary or the user will have to accept current capability.

### Design Stability

The program office has made progress toward meeting its goal of releasing 90 percent of the design drawings by design readiness review, scheduled for August 2005. This will be 9 months sooner than anticipated last year, due to the acceleration of key program dates to meet Special Operations Command requirements. Currently, 48 percent of the design drawings are complete and could be released to manufacturing. Program officials stated they are committed to meeting the required 90 percent drawing release by design review.

The modernization effort is divided into a number of capability spirals due to the various aircraft designs. The first spiral will outfit C-130 aircraft with core capabilities and an integrated defensive system. Special Operations C-130 aircraft will be outfitted first, and future spirals are planned for these aircraft because they require additional, and unique, defensive systems integration and enhanced situational awareness.

### Other Program Issues

Funding reductions in fiscal years 2003 and 2004 delayed the C-130 AMP's development program, which resulted in a rescheduling of program milestones and rebaselining of the program. The design review, low-rate initial production, and

production readiness decisions were all delayed. While program officials stated that the delay in schedule would provide more time to resolve issues with the TF/TA technology and software, the delay in fielding was not acceptable to the Special Operations Command. They added funding to mature the TF/TA technology through a series of flight demonstrations prior to the formal developmental test and evaluation period. The system integration schedule was compressed by 9 months by accelerating installation of core and mission-unique capabilities on Special Operations aircraft; however, this allows less time to reduce manufacturing risks and further compresses an already optimistic time line.

The program is also at risk if less software is reused than originally estimated, which may cause an increase in development costs and delay the program's schedule. Software integration remains a risk due to its complexity, number of suppliers, potential for developmental growth, certification of a secure operating system, and software safety standards. The program office is working to mitigate these risks through modeling and simulation, utilizing the systems integration laboratory built by the contractor, and through flight demonstrations.

### Agency Comments

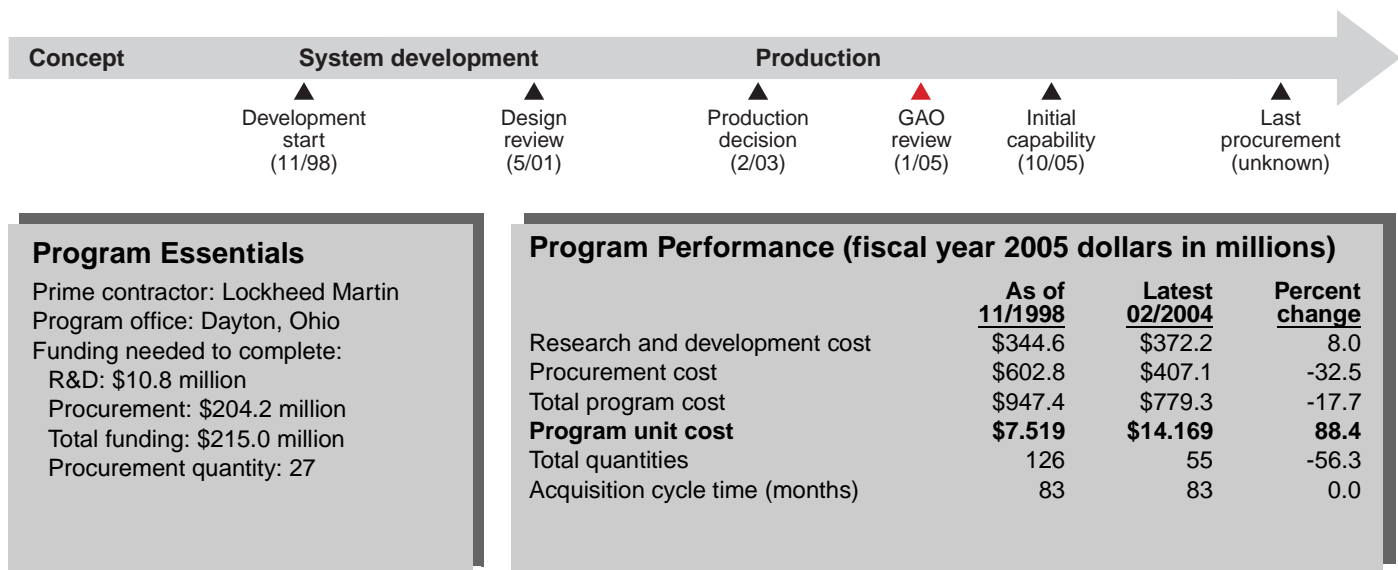
In commenting on a draft of this assessment, the Air Force stated that program officials worked with the user to agree on initially fielding TF/TA capability between 250 and 1,000 feet and that an analysis will be accomplished to determine residual TF/TA technology capability to fly lower. The Air Force also commented that funding reductions in fiscal years 2003 and 2004 delayed the C-130 AMP development program. It further stated that a delay in fielding MC-130 Combat Talon aircraft until fiscal year 2010 was unacceptable to the Special Operations Command, which added funding to mature TF/TA technology through flight demonstrations prior to a formal developmental test and evaluation period. The Air Force also commented that the special operations warfighter needs are driving an aggressive schedule.

## C-5 Avionics Modernization Program (C-5 AMP)

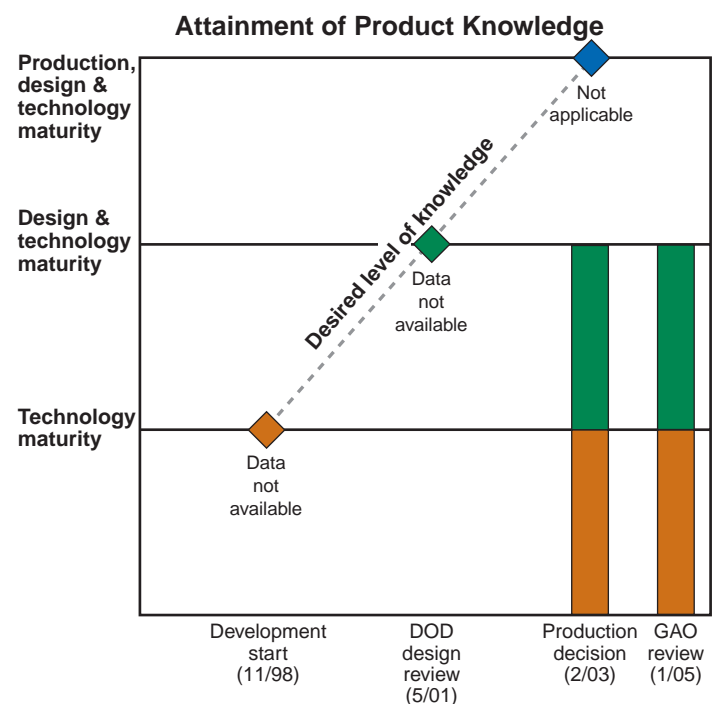
The Air Force's C-5 AMP is the first of two major upgrades for the C-5 to improve the mission capability rate, transport capabilities and reduce ownership costs. The AMP implements Global Air Traffic Management, navigation and safety equipment, modern digital equipment, and an all-weather flight control system. The second major upgrade, the C-5 Reliability Enhancement and Reengining Program (RERP), replaces the engines and modifies the electrical, fuel, and hydraulic systems. We assessed the C-5 AMP.



Source: Lockheed-Martin Aeronautics Company.



The program office considers the C-5 AMP's critical technologies and design to be mature as they are relying on commercial-off-the-shelf technologies that are installed in other commercial and military aircraft. The C-5 AMP plans to complete developmental test and evaluation in December 2004, a 2 month slip from last year. The main challenge to the program is the development and integration of software—to which this schedule delay has been attributed. The Air Force plans to modify 55 of the 112 C-5 aircraft. The Air Force is also seeking funding to modify the remaining 57 C-5s, however, that decision will not be made until the Air Force determines the correct mix of C-5 and C-17 aircraft needed to meet DOD's airlift needs. If the Air Force decides to use the C-17s, it may not upgrade some, or all, of the remaining 57 C-5s.



## C-5 AMP Program

### Technology Maturity

We did not assess the C-5 AMP's critical technologies because the program used commercial technologies that are considered mature. Program officials stated that those technologies are in use on other aircraft and that they have not significantly changed in form, fit, or function. For example, the new computer processors are being used in the Boeing 777, 717, other commercial aircraft, the KC-10, and a Navy reconnaissance aircraft.

### Design Stability

The design appears stable as the contractor has released 100 percent of the drawings for the AMP. In addition, seven major subsystem-level design reviews were completed, and integration activities are currently ongoing. Demonstration of these integration activities is scheduled during development test and evaluation, which started in December 2002 and should be completed in December 2004.

### Production Maturity

We could not assess the production maturity because most components are readily available as commercial-off-the-shelf items. This equipment is being used on other military and commercial aircraft. In addition, the C-5 AMP is incorporating many other off-the-shelf systems and equipment, such as the embedded global positioning system, the inertial navigation system, and the multifunction control and display units. To ensure production maturity, the program office is collecting data regarding modification kit availability and the installation schedules.

### Other Program Issues

Program officials indicated the greatest risk to the AMP is software development and integration. Several new software programs must be developed and integrated with several other commercial off-the-shelf software packages. According to officials, the 2 month slip in development test and evaluation can be attributed to software development delays as well as overall systems integration (hardware and software) delays. More specifically, program officials stated that the two primary causes for delays were (1) the unavailability of systems integration facilities, including equipment, simulation software, and

engineering simulator, and (2) less robust than expected integration test scripts and computer software configuration item designs. Program officials stated that they have applied lessons learned from the AMP experience to the RERP program. The C-5 RERP is assessed elsewhere in this report.

The overall quantity of the C-5 fleet has been reduced from 126 to 112 due to the retirement of 14 aircraft. The C-5 aircraft must undergo the AMP modifications prior to the RERP modifications. However, only 55 aircraft have been approved for the AMP upgrades, while 112 are awaiting the RERP upgrades. The Air Force needs to determine how many of the remaining 57 C-5s will receive the AMP upgrades. That decision will not be made until it determines the correct mix of C-5 and C-17 aircraft needed to meet DOD's airlift needs. According to program officials, the Air Force is currently performing mobility studies that will be used to make a mobility mix decision. Until it is decided whether to use C-17s to replace some, or all, of the earlier 57 C-5s, the number of aircraft to undergo the AMP and RERP modernization will remain uncertain.

### Agency Comments

In commenting on the draft of this assessment, the Air Force stated that the unit cost comparison between the November 1998 and the latest AMP position does not accurately portray the program's cost growth. The November 1998 position represents the original 126-aircraft program. The program has since been restructured to a 55-aircraft program. According to the Air Force, such a change would increase unit costs by a large amount because it would be less expensive, on a unit cost basis, to procure for a greater number of aircraft than it would be to procure for fewer aircraft.

### GAO Comments

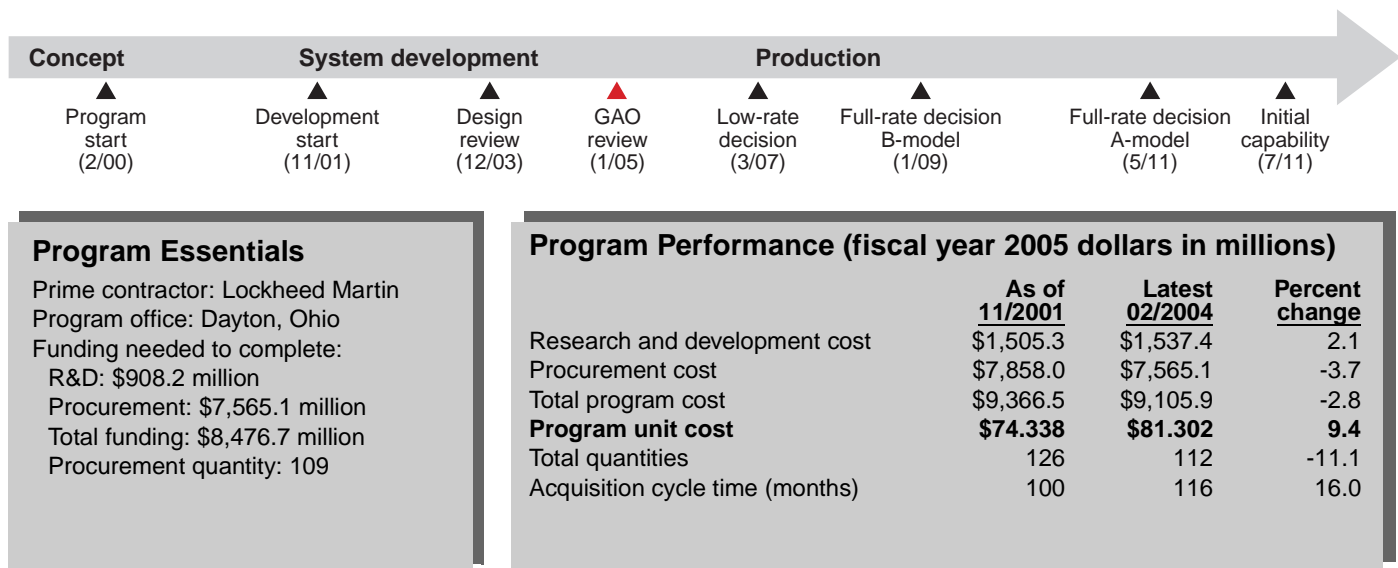
While the program has established a new cost and performance baseline since the November 1998 decision to begin development, the comparison presented provides an accurate picture of change since that major decision. Although DOD may update its baseline for management purposes, our goal is to provide an aggregate or overall picture of the program's history.

## C-5 Reliability Enhancement and Reengining Program (C-5 RERP)

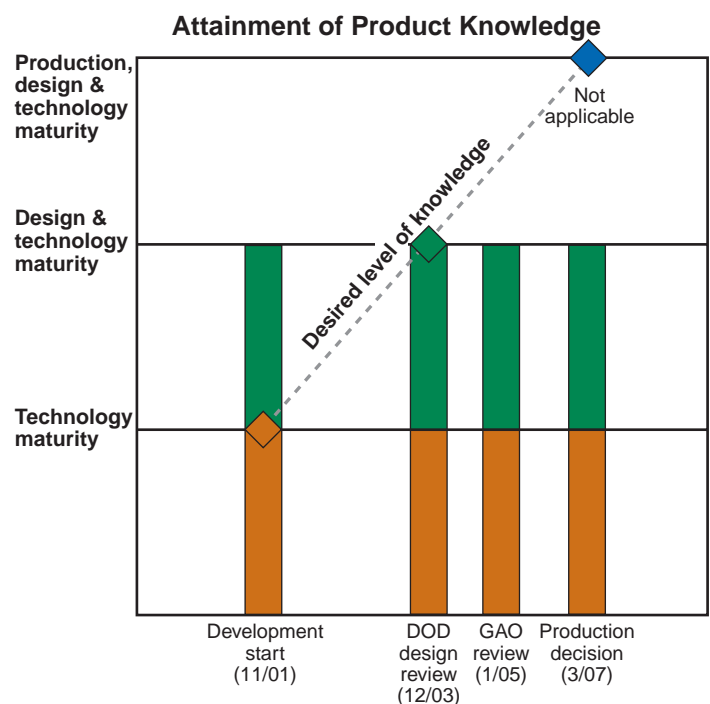
The Air Force's C-5 RERP is one of two major upgrades for the C-5. The RERP is designed to enhance the reliability of the aircraft through the replacement of engines and modifications to subsystems such as the electrical, fuel, hydraulic and flight controls systems, while the C-5 Avionics Modernization Program (AMP) is designed to enhance the avionics. These upgrades are part of a two-phased modernization effort to improve the mission capability rate, transport capabilities and reduce ownership costs. We assessed the C-5 RERP.



Source: Lockheed-Martin Aeronautics Company.



The RERP is utilizing demonstrated commercial off-the-shelf components that require little or no modification. The program ensured that the technology was mature and that the design was stable at critical points in development, closely tracking best practice standards. The program is currently in system development and plans to enter low-rate production in March 2007. The major challenge to the program is software development and integration. Also, the program is dependent on the number of aircraft approved to undergo the C-5 AMP modernization program. Until additional aircraft are approved for the AMP, it is uncertain how many aircraft will undergo the RERP.



## **C-5 RERP Program**

### **Technology Maturity**

The C-5 RERP's technologies are mature based on an independent technology readiness assessment conducted in October 2001. New engines account for 64 percent of the expected improvement in mission capability rate for the aircraft. The new engines are commercial jet engines currently being used on numerous aircraft. According to the Air Force technology assessment, these engines have over 70 million flying hours of use.

### **Design Stability**

The C-5 RERP's design is stable. As of November 2003, 98 percent of the design drawings were complete. In addition, the seven major subsystem-level design reviews were completed before the December 2003 system-level design review.

According to program officials, the greatest risk to the RERP is software development and integration activities. Several new software programs must be developed, and these programs as well as other commercial off-the-shelf software packages must be integrated. The program has experienced software problems in the past and has taken actions to improve software activities. The program is taking advantage of AMP-developed products and lessons learned in the RERP to reduce the risk of schedule slips associated with software development and integration. For example, according to program officials, the baseline software and systems integration facilities that were developed for the AMP will not have to be completely redeveloped for RERP activities.

### **Production Maturity**

We did not assess the C-5 RERP's production maturity because the Air Force is buying commercially available items. However, we expect that production maturity would be at a high level because the engines have been commercially available for many years.

### **Other Program Issues**

The C-5 RERP is dependent on the C-5 AMP (assessed elsewhere in this report), as the aircraft has to undergo avionics modernization prior to other enhancements. Over the past year, software development resources that were planned for the

RERP were shifted to the AMP to ensure completion of its software activities. According to program officials, while shifting of resources currently has not caused a significant schedule slip to the RERP, they do acknowledge that it will have a greater impact on the RERP if the AMP continues to slip and resources originally planned for use on the RERP are retained to complete the AMP work.

Due to the retirement of 14 aircraft, the quantity of C-5 RERP aircraft was reduced from 126 to 112. Although the RERP program has been authorized for 112 aircraft, the avionics modernization has only been authorized for 55 aircraft. Therefore, until the Air Force decides on how many C-5 aircraft will undergo avionics modernization, it is uncertain how many aircraft will undergo the RERP. That decision is contingent upon the results of ongoing mobility studies that are examining the appropriate mix of C-5 and C-17 aircraft for DOD's overall airlift needs.

### **Agency Comments**

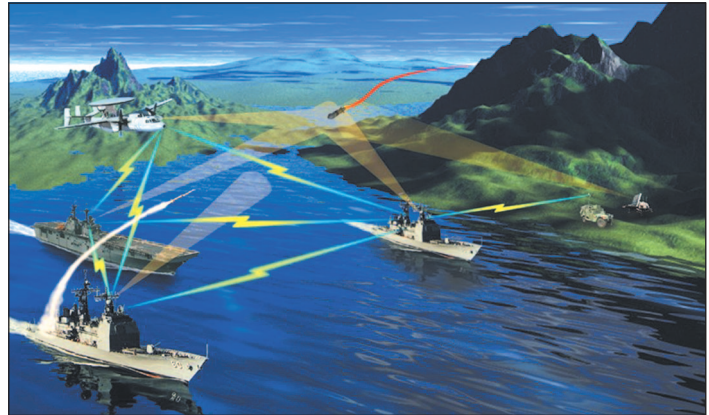
In commenting on the draft of this assessment, the Air Force stated that the unit cost comparison between the November 2001 and the latest RERP position does not accurately portray the program's cost growth. The November 2001 position represents the original 126-aircraft program. The program has since been restructured to a 112-aircraft program. It further stated that such a change would increase unit costs by a large amount because it would be less expensive, on a unit cost basis, to procure for a greater number of aircraft than it would be to procure for fewer aircraft.

### **GAO Comments**

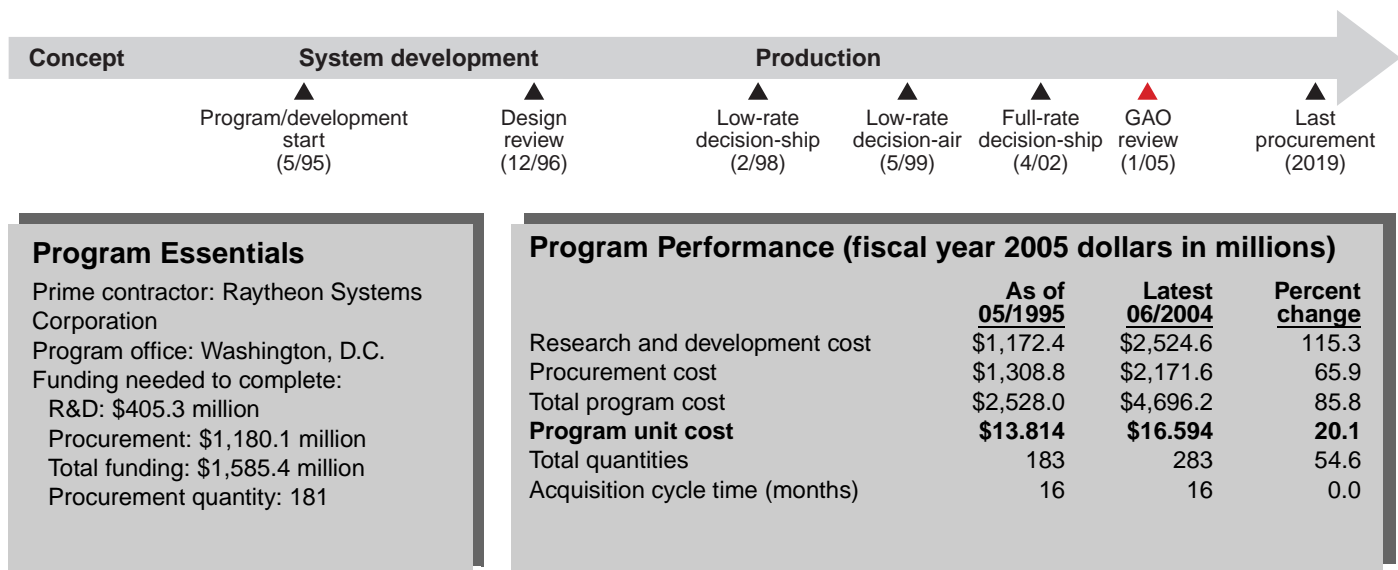
While the program has established a new cost and performance baseline since the November 2001 decision to begin development, the comparison presented provides an accurate picture of change since that major decision. Although DOD may update its baseline for management purposes, our goal is to provide an aggregate or overall picture of the program's history.

## Cooperative Engagement Capability (CEC)

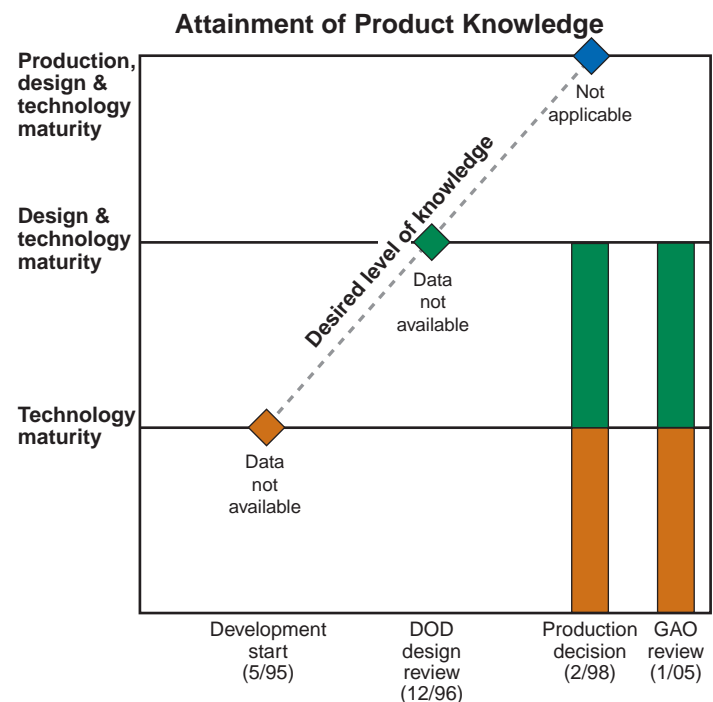
The Navy's CEC is designed to connect radar systems to enhance detection and engagement of air targets. Ships and planes equipped with their version of CEC hardware and software will share real-time data to create composite radar tracks—allowing the battle group to see the same radar picture. A CEC-equipped ship can then detect and engage targets its radar cannot see. We assessed the current shipboard and airborne versions of the CEC.



Source: CEC Program Office.



The CEC's production maturity could not be assessed because the government does not collect the necessary data on the commercially available portions of the ship-based and airborne versions of the CEC. However, program and contractor officials consider the production processes capable of producing a quality product on time and within cost. The technologies and design of both the ship-based and airborne versions of the CEC are fully mature. In April 2002, the shipboard version was approved for full-rate production. The airborne version remains in low-rate production and may proceed to full-rate production pending a full-rate production decision anticipated in September 2005.



## CEC Program

### Technology Maturity

All six of the CEC's critical technologies are mature. While the shipboard and airborne versions have different hardware, they share the same critical technologies.

### Design Stability

The CEC's basic design appears stable, as all of the drawings needed to build the shipboard and airborne versions have been released to manufacturing. Additional drawings for each version continue to be released to incorporate advances in commercially available technologies, which comprise approximately 60 percent of CEC hardware.

### Production Maturity

We could not assess production maturity as data were not available. According to program officials, CEC production is mature and noncommercial portions do not involve critical manufacturing processes. Officials indicated that they do not have insight into whether the manufacturing processes for the commercial portions are critical and are under statistical control. However, program officials are confident that a quality product can be delivered on time and within cost given contractor past performance.

The program office plans to seek full-rate production approval for the airborne version in September 2005. During operational testing, the airborne version was determined to be operationally effective but not operationally suitable. According to the program office, it is implementing corrections that will be verified in time to support the full-rate production decision.

### Other Program Issues

In November 2003, the Navy announced plans to improve CEC interoperability by pursuing open architecture and functionality changes with the Joint Single Integrated Air Picture Systems Engineering Organization (JSSEO). The CEC Program Office discontinued planning for a Block 2 development effort and began working with JSSEO to jointly engineer sensor measurement and radar tracking management solutions that will be available to all services to ensure optimum interoperability across the battlespace. The joint track management

software being developed is intended to interface with CEC software to improve data sharing throughout different computing environments and to facilitate component upgrades without redesigning the entire system.

CEC officials consider the joint track management software a technical risk since JSSEO is using a relatively new approach for combat system software development. The officials also consider it a schedule risk that could impact timely delivery of Navy platforms, including the DD(X) and the Littoral Combat Ship, which are to be equipped with CEC. To mitigate risks, the CEC program manager is closely monitoring joint track manager progress to determine whether the software can be incorporated into the CEC on schedule. If JSSEO does not deliver an acceptable product by September 2005, the Navy plans to continue using current CEC software and explore alternatives.

With discontinuation of a Block 2 effort, the program also initiated a preplanned product improvement effort for CEC hardware. This effort takes advantage of advances in technology to reduce size, weight, and cost without adding new critical technologies. Improved hardware will operate with current CEC software and joint track manager software, once ready. The program began testing of the improved hardware in August 2004 and plans to obtain Office of the Secretary of Defense approval for incorporating improvements by October 2005. The program is also developing a miniterminal land version for the Marine Corps.

### Agency Comments

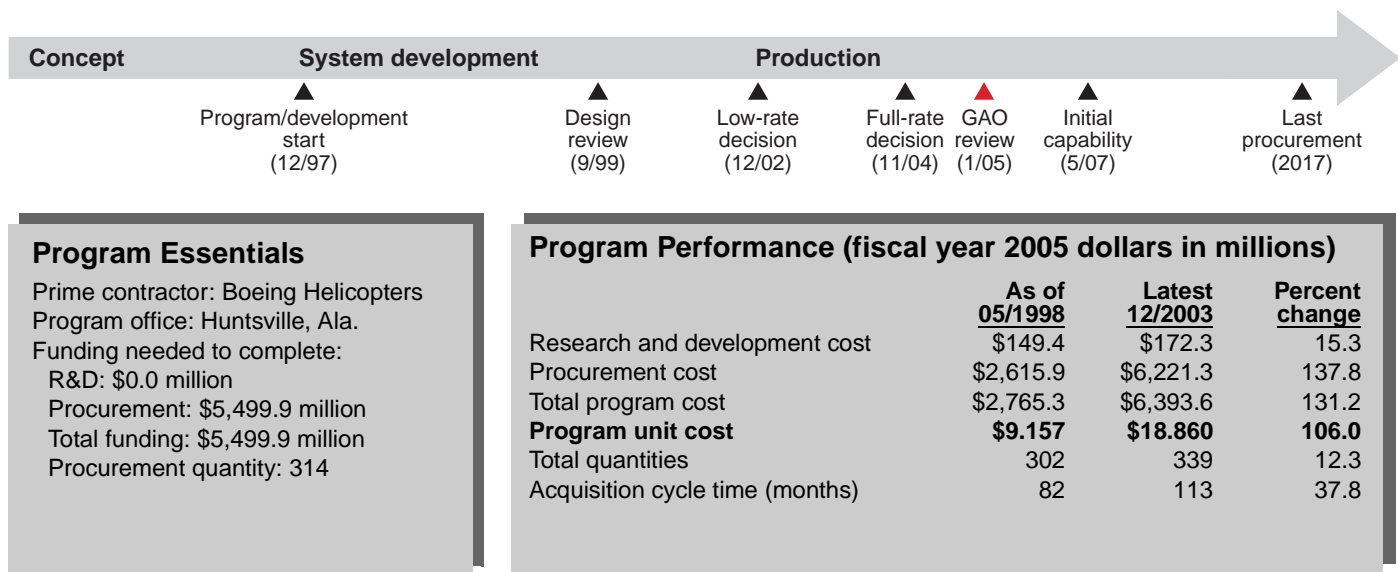
In commenting on a draft of this assessment, the Navy stated that it generally concurred with our assessment but provided clarifying comments. Regarding the schedule risk associated with joint track management, the Navy stated that it, along with the other services, is working with JSSEO to reach agreement on a joint architecture for track management, combat identification, and tactical data link integration. It explained that the joint architectural agreement will allow appropriate existing solutions to be integrated into the joint track manager and will be extensible to multiple networks and different communication devices. The Navy stated that this will reduce the risk of providing joint track management capability in fiscal year 2008.

## CH-47F Improved Cargo Helicopter (CH-47F)

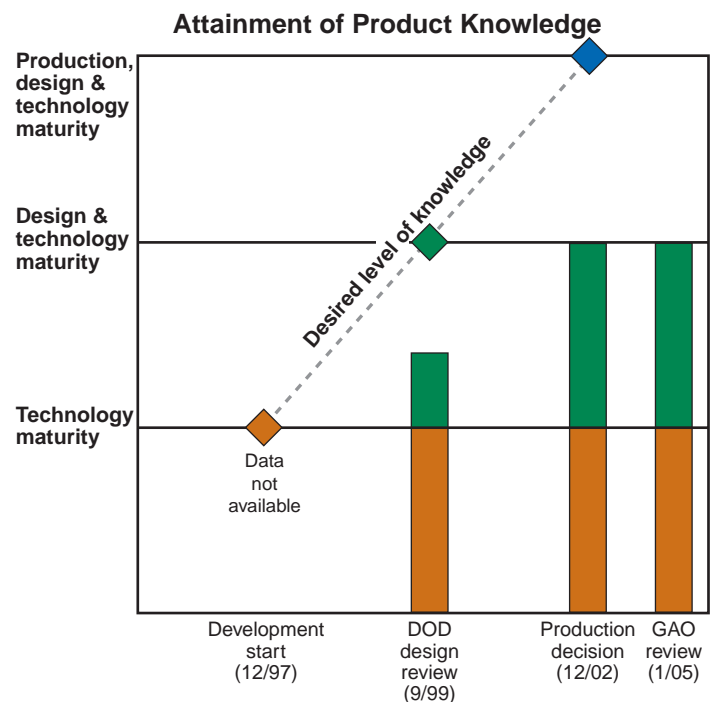
The Army's CH-47F heavy lift helicopter is intended to provide transportation for tactical vehicles, artillery, engineer equipment, personnel, and logistical support equipment. It is also expected to operate in both day and night. The program is to enhance performance and extend the useful life of the CH-47. This effort includes installing a digitized cockpit, rebuilding the airframe, and reducing aircraft vibration.



Source: Boeing Helicopters.



CH-47F production maturity could not be assessed as the program is not collecting statistical process control data on key manufacturing processes. Program officials believe that CH-47F production is low risk because no new technology is being inserted into the aircraft, two prototypes have been produced, and the production process was demonstrated during the delivery of one low-rate initial production aircraft. The CH-47F technologies appear mature and the design stable, with 100 percent of the engineering drawings released for manufacturing. The Army has regained 6 months of a schedule delay anticipated when it was directed to produce additional MH-47s for special operations.



## CH-47F Program

### Technology Maturity

We did not assess technology maturity or determine the number of critical technologies in detail. The CH-47F is a modification of the existing CH-47D helicopter. Program officials believe that all critical technologies are mature and have been demonstrated prior to integration into the CH-47F development program.

### Design Stability

The Army completed the CH-47F engineering development and manufacturing phase, with 100 percent of the drawings released to manufacturing. However, at the design review, only 37 percent of the system's engineering drawings were complete. Since that time, the number of drawings completed increased substantially. The majority of the new drawings were instituted to correct wire routing and installation on the aircraft; changes the program office believed could not be determined until after the first prototype was delivered.

### Production Maturity

We did not assess production maturity because the CH-47F program does not collect statistical process control data on its production of helicopters. The program office relies on inspections as its means to ensure acceptable production results.

According to the program office, the CH-47 production is low risk because two prototypes have been produced during development and the Army recently took delivery of its first low-rate initial production aircraft. Further, the program reported that during low-rate production, it made significant advances in the development and refinement of the system that are designed to increase production efficiencies. Advances include the implementation of the automated management execution system and the introduction of laser tracking to identify key mounting points. These enhancements are geared toward improving the manufacturing learning curve. However, the program office acknowledges that the program will lose some of the learning benefits during the anticipated break in production of the CH-47F in favor of producing more MG-47s during the next lot of production.

### Other Program Issues

In 2002, DOD directed the Army to produce 16 MH-47G aircraft for the Special Operations Command before the start of the Army's low-rate production for the CH-47F helicopters and to deliver those aircraft as soon as possible. The Army initially estimated that this transfer of 16 aircraft for special operations would result in a 15-month delay in its first unit equipped date for the CH-47F. However, according to the program office, scheduling issues between the Army and the Special Operations Command have been resolved. The Army now estimates that the 15-month schedule slip has been reduced by about 6 months. The program office reported that the CH-47F and MH-47G program strategy has been approved by the Defense Acquisition Executive.

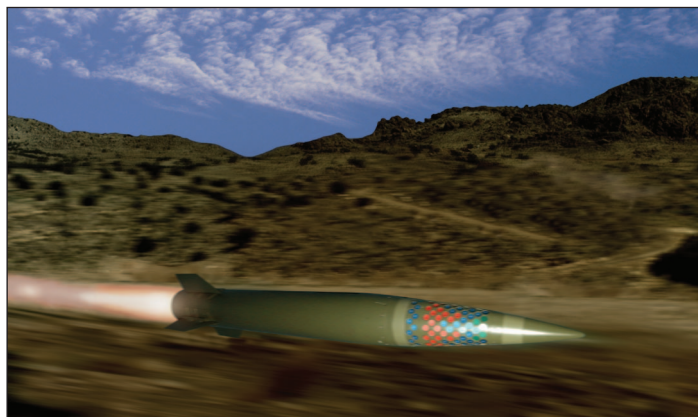
Further, the Army has recently approved the production of additional CH-47F aircraft in the most recent Program Objective Memorandum submission. Additionally, the Army included in this submission an escalation of 19 CH-47F aircraft that had previously been scheduled at the end of the program. These quantity changes resulted from the recent Army Aviation Transformation Group's recommendations.

### Agency Comments

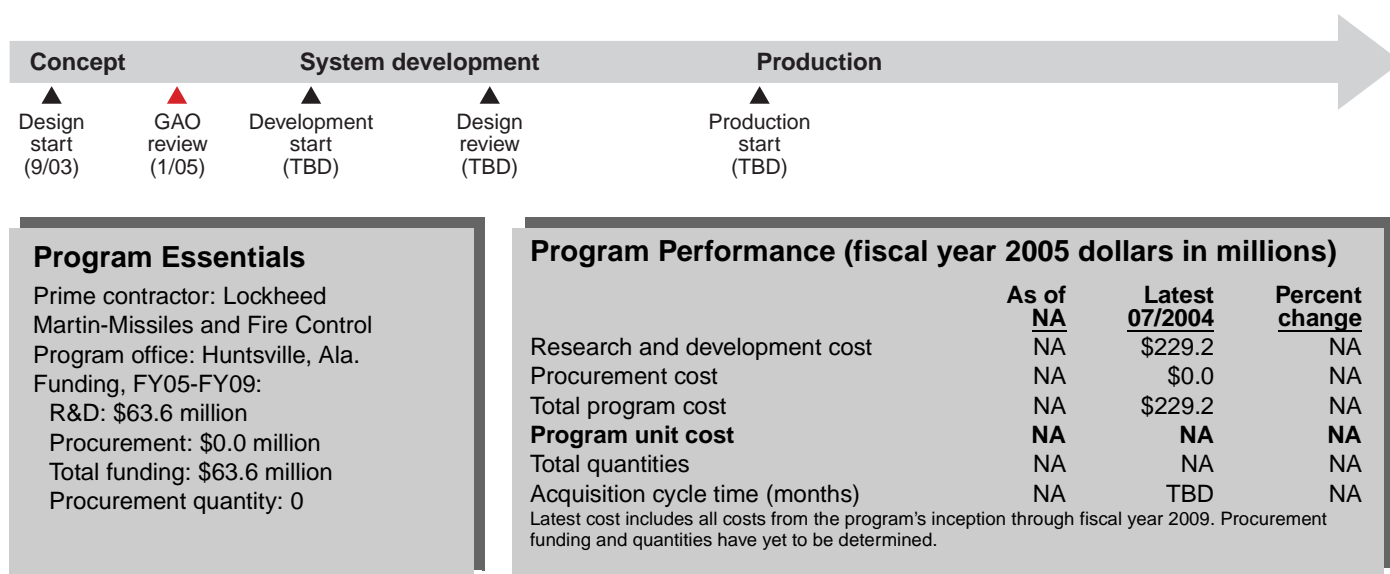
The Army concurred with this assessment and provided technical comments, which were incorporated where appropriate. Additionally, it commented that the full-rate production decision was approved on November 22, 2004, by the Army Acquisition Executive. Further, the program was rebaselined to include a revised Acquisition Objective of 510 aircraft. Details of this rebaselined program will be outlined in the December 2004 Selected Acquisition Report.

## Compact Kinetic Energy Missile (CKEM)

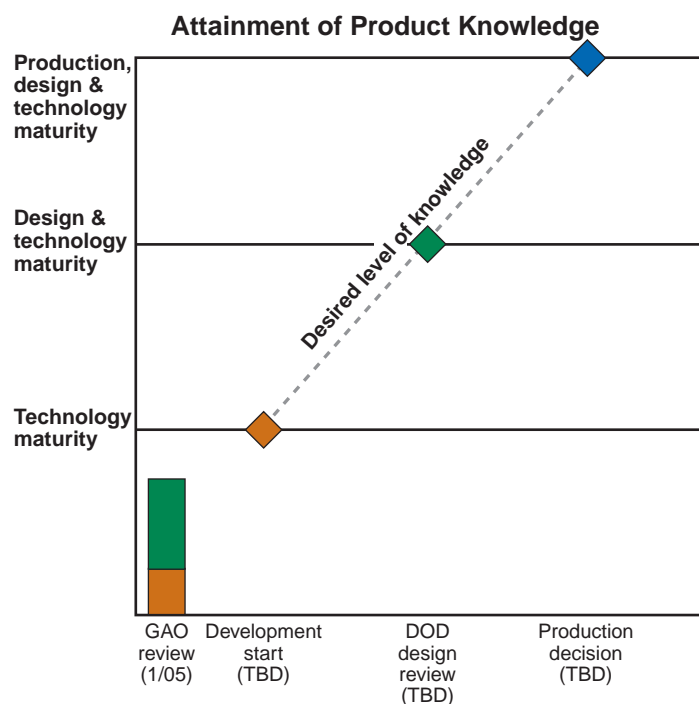
The Army's CKEM is a hypervelocity missile designed to provide superior lethality against current tanks, bunkers, buildings, and future advanced threat armor. It is designed to provide a high rate of fire and a high probability of kill beyond the range of tank guns, and at half the size and weight of current kinetic energy missiles. The CKEM is a potential candidate for use on the current Stryker Brigade and Future Combat System vehicles. The Army is currently developing the CKEM in an Advanced Technology Demonstration program.



Source: Lockheed-Martin--Missiles and Fire Control; Dallas, Texas.



Program officials believe the CKEM technologies will be mature when the program enters system development. The Army is using an advanced technology demonstration to develop the CKEM technologies to satisfy future Army missile requirements. The technologies have already been demonstrated in a relevant environment. Work remains to reduce the technologies to the right size and show they can withstand the high g-force environment. Funding inconsistencies and increased costs have hampered technology development efforts and increased program risk. Program officials expect at least one design change iteration once the CKEM enters system development, which could happen in 2006 after full-scale weapon system flight testing.



## **CKEM Program**

### **Technology Maturity**

Although none of its critical technologies are fully mature, the CKEM is over a year from entering system development and all four technologies have been demonstrated in a relevant environment. Program officials believe all CKEM critical technologies will be fully mature when the program proceeds with system development. The missile's four critical technologies are a solid rocket motor, an attitude control system, penetrator/lethality mechanisms, and guidance systems. CKEM engineers are pioneering many of the system's technologies to satisfy future missile requirements, which include reduced infrared signatures, longer ranges, nondetonable propellants, and smaller size and weight.

Existing missile guidance and control components will not satisfy the size and weight requirements and will not withstand the g-forces potentially exerted by the CKEM. As a result, CKEM developers are working to miniaturize existing components and improve tolerances for use under greater velocities. The program completed testing of smaller guidance and control prototypes in a high g-force environment. Engineers are also designing a motor with an increased burn rate, advanced materials, and innovative structural designs. They successfully tested a new solid-fuel rocket motor, and they plan to begin controlled flight testing in April 2005. They also demonstrated the missile's lethality against a tank target with advanced armor. However, system officials said that additional technology funding is needed to fully develop component technologies and produce a missile that will meet the size and performance goals.

Program officials believe they can mature technologies to the point that only a single design iteration will be needed to satisfy Army objective requirements during system development. They noted that the Assistant Secretary of the Army for Acquisition, Logistics, and Technology instructed them to forego involvement in the development of fire control systems and instead focus solely on missile development. This could result in integration problems that would require future design changes.

### **Other Program Issues**

Program officials believe that inconsistent funding has hampered development efforts. Over the last 3 years, the budget has been reduced over \$21 million. Those reductions were offset by reprogramming \$17 million back into the program. Initially, competitive contracts were awarded to two prime contractors. Citing funding discontinuity and higher-than-expected contractor proposals, program officials did not exercise an option for the second contractor's continued involvement. They also cited funding as the reason the Army suspended international cooperative agreements for assistance in developing associated technologies.

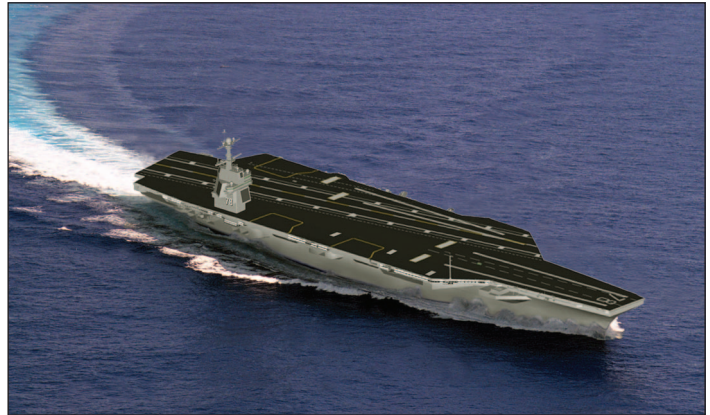
The Army has not included a CKEM system development program in its future funding plans. Nonetheless, program officials hope to have the system ready to transition to system development in late 2006. CKEM technologies can also be used to improve existing kinetic energy missiles, namely the Line-of-Sight Anti-Tank missile.

### **Agency Comments**

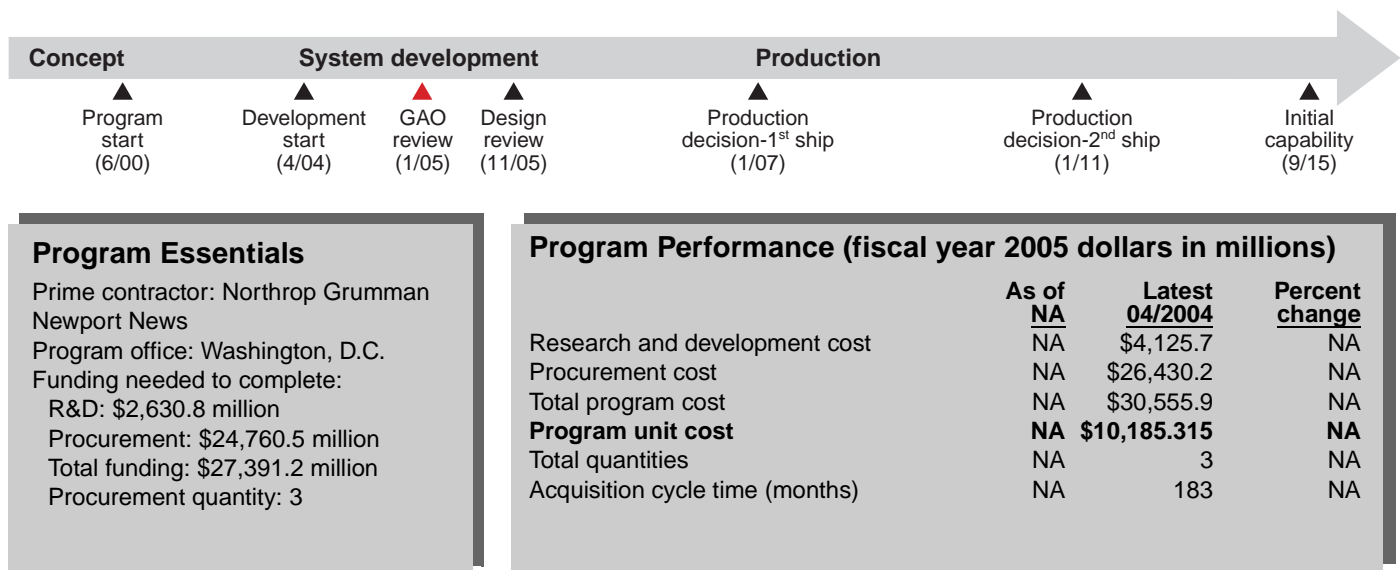
The Army concurred with our assessment.

## Future Aircraft Carrier CVN-21

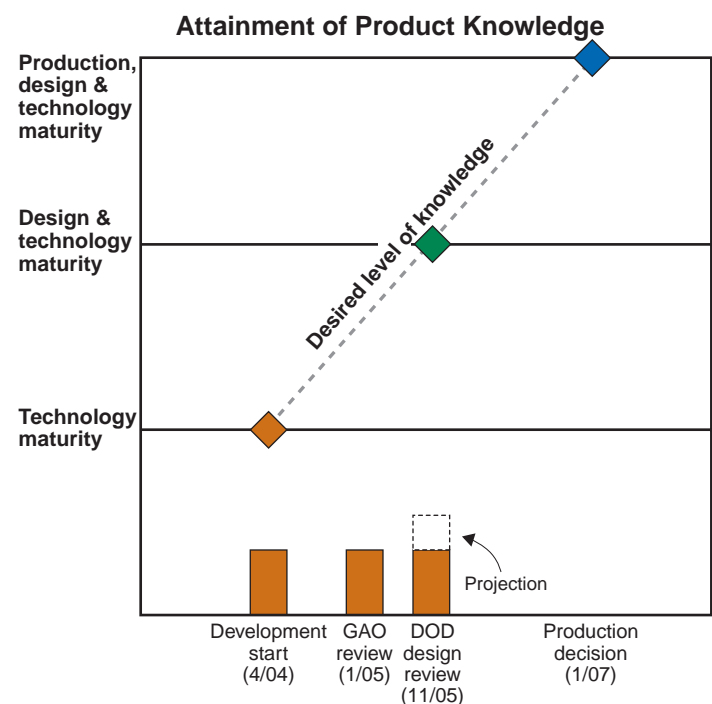
The Navy's CVN-21 class is the successor to the Nimitz-class aircraft carrier and includes a number of advanced technologies in propulsion, aircraft launch and recovery, weapons handling, and survivability. These technologies will allow for increased sortie rates and decreased manning rates as compared to existing systems. Many of the technologies were intended for the second ship in the class, but they were accelerated into the first ship in a December 2002 restructuring of the program.



Source: CVN-21 Program Office.



The CVN-21 entered system development in April 2004 with very few of its critical technologies fully mature. This is due in part to DOD's decision to accelerate the installation of a number of technologies from the second ship to the first. The accelerated technologies are at much lower levels of maturity. Program officials state that the extended construction and design period that ends in 2014 allows further time for technology development. Program officials have established a risk reduction strategy that includes decision points for each technology's inclusion based on a demonstrated maturity level. These points coincide with key design milestones and include consideration of the fallback use of mature technologies for all but two technologies. The program office has stated that those two technologies are already mature and operational.



## CVN-21 Program

### Technology Maturity

Program officials reported that 3 of the 14 critical technologies were mature at development start and that 4 more were approaching maturity. An additional 7 were at much lower levels of readiness. The Navy expects that 10 of the 14 technologies will be mature or close to mature by the design review in fiscal year 2006.

Some of the CVN-21 critical technologies are being developed by other programs, not by the CVN-21 program. As a result, events in those programs could affect the CVN-21 development time line. Those technologies are the Volume Search Radar, Multi-Function Radar, Advanced Arresting Gear, Evolved Sea Sparrow Missile and Joint Precision Approach and Landing System. CVN-21 program officials reported that they are working closely with all critical technology leads in those offices to ensure that their time lines are integrated with the needs of the CVN-21 program. In case those technologies do not mature in time for insertion into the carrier, the CVN-21 program has identified existing or fully mature alternate systems as backup technologies.

Since entering development, the program office has added 9 1,100-ton air conditioning plants as a critical technology, and has added them to the baseline design for the ship. The plants are not near maturity. The Navy added the plants because the CVN 21's requirements for chilled water are significantly higher than existing aircraft carriers. The Navy considers this a low-risk development effort since they are using a proven commercial design with upgrades to meet military shock, vibration, and noise requirements.

Two of the four remaining technologies that are not mature, the Omni-Directional Vehicle and Automated Weapons and Materials Movement Technologies, are primarily mobile vehicles that can be accommodated late in the design and construction schedule because they are not installed as part of the ship. In addition, the Advanced Arresting Gear is not near maturity, but according to program officials, it does not pose a significant risk to the program because it is located high in the ship and as such will be integrated in the latter stages of construction.

Program officials stated that it is not possible to mature some systems to the best practices standard this early in development. One such system is the Electromagnetic Aircraft Launch System, a replacement for the current steam catapult system used to launch aircraft off carriers. This system has been in development since the late 1990s, but due to the size and complexity of the system, a prototype of it cannot be tested aboard a surrogate ship.

### Other Program Issues

Program cost estimates increased by more than \$18 billion over the amount reported last year as a result of the development start decision, which added a second follow-on ship to the program, for a total production run of three ships. Previous estimates were based on a single follow-on ship and were not fully developed estimates for the entire program. In addition, the cost estimates at development start more accurately reflect potential inflation incurred by the shipbuilder during design and construction of the ship.

### Agency Comments

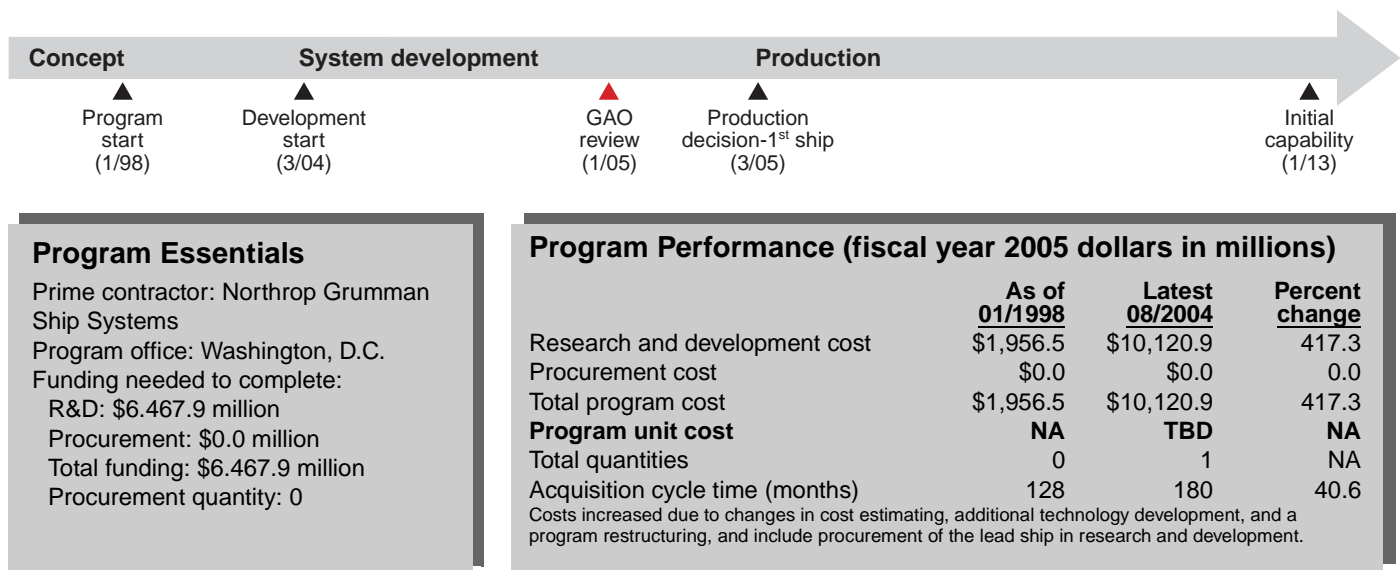
The Navy generally concurred with this assessment and reiterated that the time frames for design and construction of an aircraft carrier allow for evolving technologies to be brought to the ship later in the construction cycle. It stated that if a certain technology does not mature in time for ship construction, the technology will be replaced by a fall back technology that may not meet projected capability, but it will at least be equal to current capability.

## DD(X) Destroyer

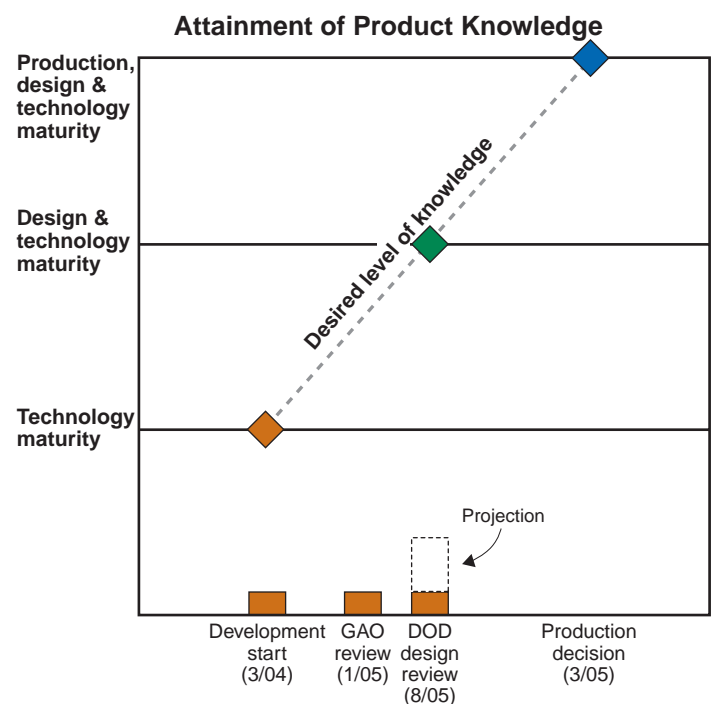
The Navy's DD(X) destroyer is a multimission surface ship designed to provide advanced land attack capability in support of forces ashore and contribute to U.S. military dominance in littoral operations. The program is currently in the system design phase, and the Navy plans to authorize detailed design and construction of the lead ship in March 2005. The Navy plans to demonstrate the ship's critical technologies by building and testing 10 developmental subsystems, referred to as engineering development models.



Source: DD(X) Program Office (PMS 500).



None of the DD(X) technologies included in the 10 engineering development models were mature at the start of development, and none are expected to be mature at the March 2005 decision to authorize detailed design and construction of the lead ship. Current plans call for demonstrating 3 of the 10 subsystems by the end of the program's design review in August 2005 and an additional 3 in September 2005. Backups are available for only 2 of the 10 developmental subsystems. As most of the testing of the engineering development models will take place in the months immediately before and after the design review, it is not likely that design stability will be achieved by the time of that review.



## **DD(X) Program**

### **Technology Maturity**

None of the DD(X) technologies were mature at the start of development, and none are expected to be mature at the March 2005 decision to authorize detailed design and construction of the lead ship. By the end of the design review in August 2005, only three subsystems are expected to complete testing: the autonomic fire suppression system, the hull form, and the infrared mock-ups. The integrated power system, peripheral vertical launch system, and total ship computing environment are expected to complete testing in September 2005. The dual band radar and integrated deckhouse are to complete testing well after the design review. The advanced gun system and undersea warfare system will not be tested as fully integrated systems until after installation on the first ship.

The current plans for the integrated undersea warfare system include testing the functionality of components, such as the ability of one of two sonar arrays to detect mines, but not demonstrating the system as a whole.

Component testing of the advanced gun system is ongoing and has resulted in changes to some components. The weight of the gun system increased as a result of an effort to improve producibility and cost efficiency. Land-based testing of the gun system is planned for the summer of 2005, and flight tests for the munition are to be completed in September 2005. The two technologies will not be tested together until after ship installation.

The dual band radar is not scheduled to complete testing until fiscal year 2008, well after the design review. Program officials have made some assumptions about where in the deckhouse it will be placed. If its weight increases or other technical factors cause it to be relocated, a redesign effort may be needed. In addition, recent component testing and design reviews of portions of the radar have revealed shortfalls in performance.

The integrated power system recently completed a change in design, which helps mitigate previously experienced weight issues. These design changes will not be tested until after design review. In addition, technical issues with components of the Permanent Magnet Motor have arisen that could

affect schedule and cost. Plans for the integrated power system do include the use of a fallback technology, but would require trade-offs in requirements.

### **Design Stability**

Most of the testing of the engineering development models will take place around the time of design review. Even if tests are successful, they will not be completed in time to achieve design stability. Problems found in testing could result in changes in the design, delays in product delivery, and increases in cost. Detailed knowledge about subsystems and their component technologies is necessary for developing the system design. If this information is not available and assumptions about operating characteristics have to be made, redesign may be necessary when reliable information is available.

### **Agency Comments**

The Navy acknowledges the aggressive DD(X) schedule but maintains that the ability to deliver revolutionary capabilities to the fleet with reduced crew necessitates some element of risk. Congress has expressed support for the Navy's approach, stating in the report accompanying the fiscal year 2005 national defense authorization act "the conferees believe that taking such risks is warranted to ensure that the DD(X) technologies are not obsolete, and that the Navy has taken adequate steps to mitigate the risks before ship construction begins."

The Navy disagrees with the assessment that the DD(X) will not achieve design stability prior to design review. It stated that the ship design is stable and reflects release of the final baseline leading to design review. It also stated that the results from continued engineering development model testing will be incorporated in the design and that permission to begin design review will be based on meeting specific entrance criteria that measure the availability of the appropriate data on technologies.

### **GAO Comments**

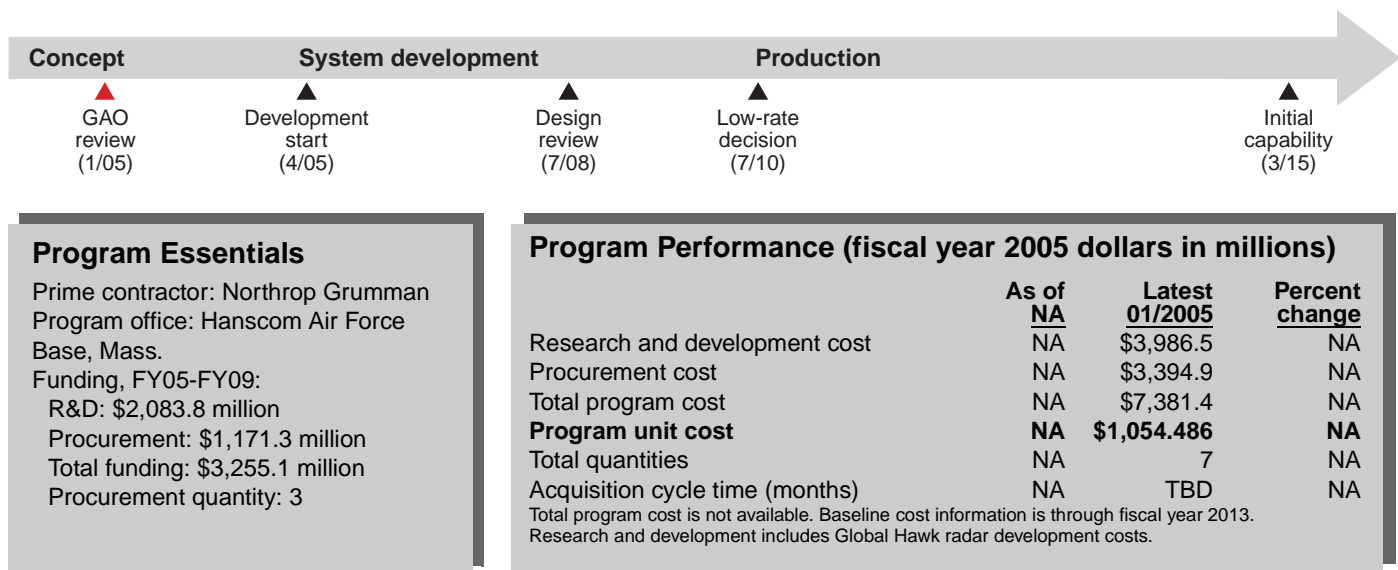
Design stability requires detailed knowledge of the form, fit, and function of all technologies as well as the integration of individual, fully matured subsystems. As testing for DD(X) technologies continues beyond the dates scheduled for design review, this knowledge may not be achieved when required.

## E-10A Multi-Sensor Command and Control Aircraft (E-10A)

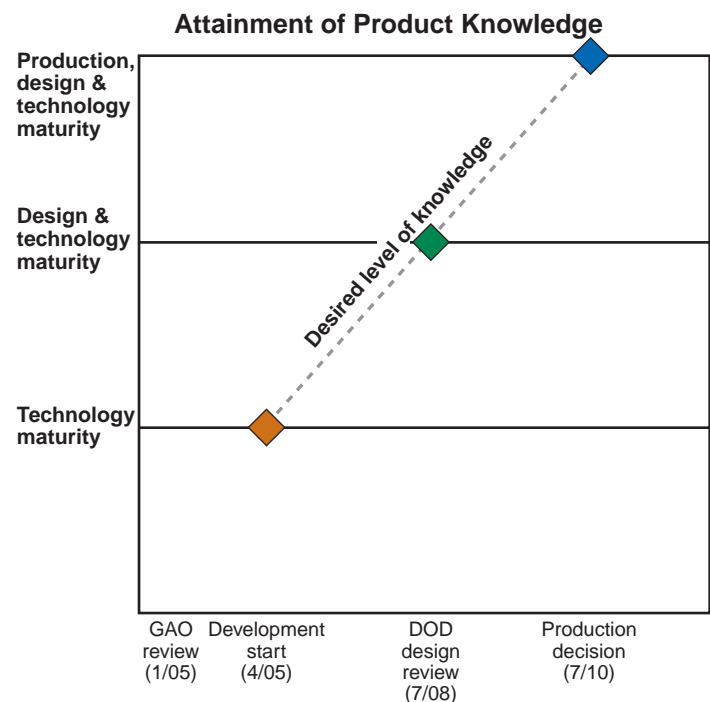
The Air Force's E-10A program is being designed to exploit emerging radar sensor technologies for airborne surface surveillance and focused air surveillance for cruise missile defense. It will consist of an active electronically scanned array radar; a modified Boeing 767 commercial airframe; and a battle management, command and control computer mission subsystem. Development of the radar has already begun; and while funding of the first airframe has begun, the overall program has not yet entered development. We assessed the entire system.



Source: E-10A/MP-RTIP Program Office.



We have not assessed the technology maturity of the overall E-10A program because program officials have not yet completed their identification and assessment of the system's critical technologies. However, they assessed the radar's critical technologies in October 2003, prior to the radar's Milestone B decision. At that time, officials determined that six of the radar's nine critical technologies were mature. The remaining three radar technologies are not expected to reach full maturity until the first E-10A flight in 2010. Development challenges for the overall E-10A program include the integration of the radar, airframe, and battle management subsystems and the software development for the battle management subsystem.



## E-10A Program

### Technology Maturity

Because program officials have not yet completed their identification and assessment of the program's critical technologies, we were unable to assess the technological maturity of the overall E-10A system. Program officials are preparing a technology development strategy as well as a technology readiness assessment in support of the upcoming development decision for the overall weapon system.

Program officials have identified and assessed the critical technologies associated with the radar subsystem. They determined that six of the nine critical technologies were mature. The remaining three radar technologies are not expected to reach full maturity until the first E-10A flight in 2010. Tests on a smaller prototype have demonstrated the functional capabilities of the radar, but are not representative of the E-10A radar's form or fit. The final form of the radar will be significantly larger and will not be integrated on the airframe until flight testing in 2010.

### Design Stability

We could not assess design stability for the E-10A as the overall system has not yet entered system development. As a result, the total number of drawings has not yet been determined. However, a final design review of the radar subsystem was conducted in June 2004. Program officials stated that over 90 percent of the expected drawings for the radar had been released at that point. They do not expect the number of radar drawings to change significantly because key subsystems for the radar are already being produced for other weapon systems.

### Other Program Issues

In fiscal years 2003 and 2005, the E-10A's proposed budget was reduced by Congress. Both budget cuts resulted in a restructuring of the program. As part of the last restructuring, program officials requested that the system development milestone decision be accelerated from July to April 2005. However, in a recent budget decision, DOD reduced the program's fiscal year 2006 and 2007 budget request by a total of \$600 million. If this reduction is sustained, the E-10A program will have to undergo yet another restructuring.

According to program officials, the software development for the battle management command and control subsystem is the most critical program risk. This subsystem will provide the machine-to-machine communications capability needed to operate with prospective and legacy command and control systems. The development of the battle management subsystem has lagged behind the radar and airframe; the Air Force just awarded a development contract for the subsystem in September 2004.

The 767 airframe is a commercial derivative that will be modified to meet the E-10A's military requirements. In addition, the integration of the large scale radar and the battle management subsystem may necessitate additional modifications. The Air Force has only contracted for one aircraft, which will be used as a testbed. As a result of the budget cuts, the delivery of this aircraft has slipped about 1 year.

### Agency Comments

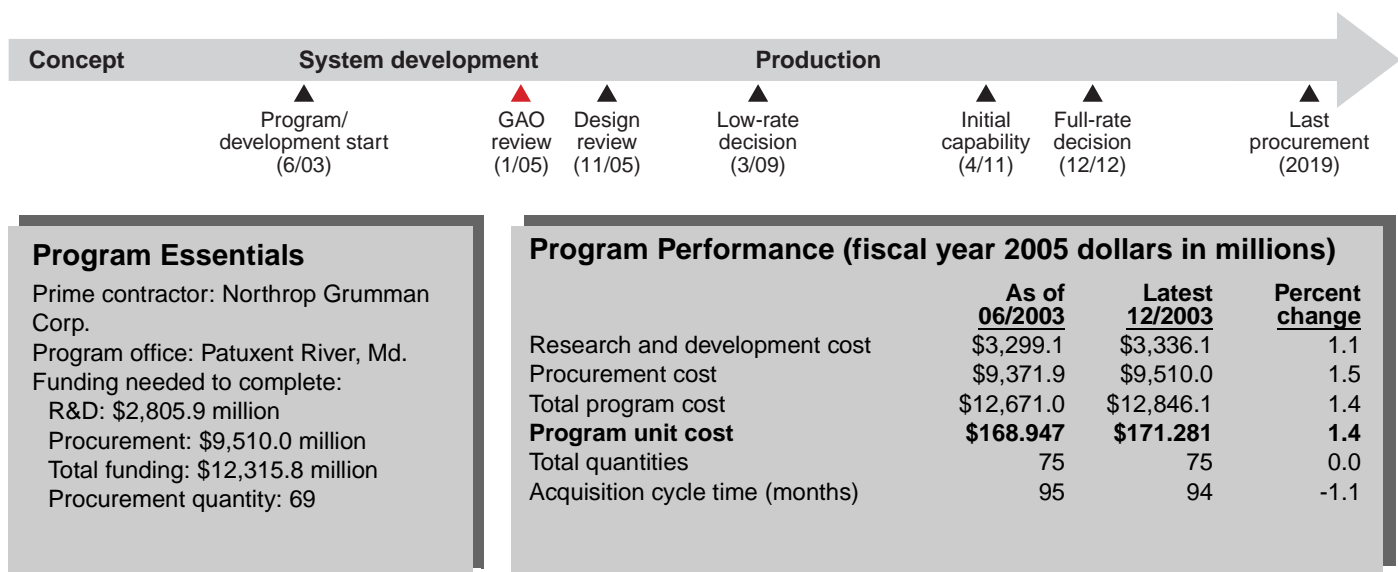
In commenting on a draft of this assessment, the Air Force stated that the E-10A program has been restructured to accommodate both an Office of the Secretary of Defense directed development decision delay and congressional budget cuts. It further noted that the restructuring has been accomplished with minimal impact to ongoing design activities and has retained the radar/E-10A synchronization necessary to deliver an E-10A weapon system that is responsive to warfighter requirements. The Air Force also provided technical comments, which we incorporated as appropriate.

## E-2 Advanced Hawkeye (E-2 AHE)

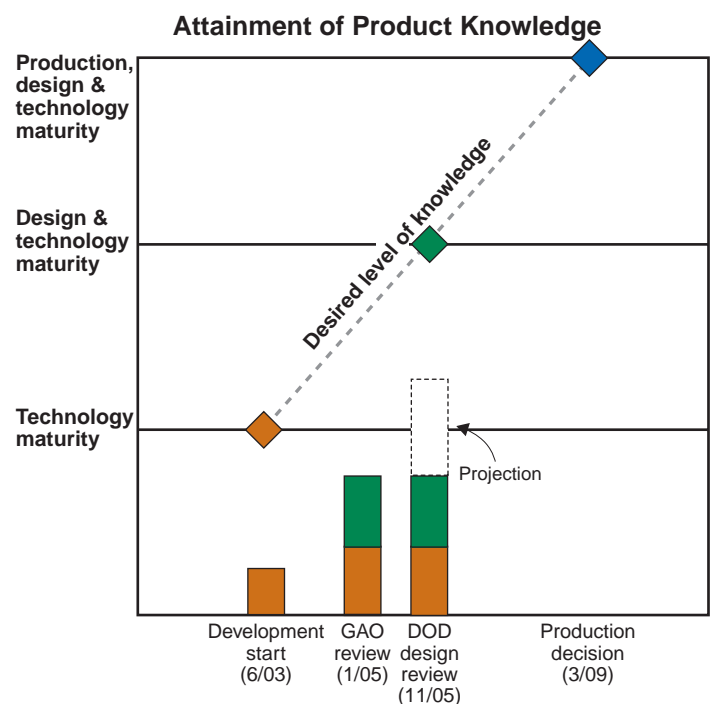
The Navy's E-2 AHE is an all-weather, twin engine, carrier-based, aircraft designed to extend early warning surveillance capabilities. It is the next in a series of upgrades the Navy has made to the E-2C Hawkeye platform since its first flight in 1971. The E-2 AHE is designed to improve battle space target detection and situational awareness, especially in littoral areas; support Theater Air and Missile Defense operations; and improve operational availability.



Source: Program Executive Officer, Tactical Aircraft Programs (PMA-231).



The E-2 AHE program entered system development in June 2003 without demonstrating that its four critical technologies had reached full maturity. Since that time, one of the program's four critical technologies has reached full maturity. Program officials do not expect to achieve maturity on the remaining three critical technologies until after the design review. While more mature backup technologies exist for the three critical technologies, use of the backup technologies would result in degraded system performance or reduced ability to accommodate future system growth. The program office has made progress on completing design drawings and plans to have the majority of drawings completed by the time of design review in November 2005. However, until the technologies are mature, the potential for design changes remains.



## **E-2 AHE Program**

### **Technology Maturity**

One of the E-2 AHE's four critical technologies (the space time adaptive processing algorithms and associated processor) is mature. The program expects the remaining technologies (the rotodome antenna, a silicon carbide-based transistor for the power amplifier to support UHF radio operations, and the multichannel rotary coupler for the antenna) to be fully mature after the November 2005 design review but before the start of production in March 2009.

More mature backup technologies exist for the three technologies (the rotodome antenna, the silicon carbide-based transistor, and the multichannel rotary coupler) and were flown on a larger test platform in 2002 and 2003. However, use of the backup technologies would result in degraded system performance or reduced ability to accommodate future system growth due to size and weight constraints. The next AHE technology readiness assessment is to be performed prior to the production decision for the system in fiscal year 2008, and the program office anticipates that the critical technologies will be mature at that time.

### **Design Stability**

The program had completed almost 35 percent of its engineering drawings at the time of our review. Program officials project that they will have 81 percent of the drawings completed by the time of design review in November 2005, and 100 percent completed by the planned start of production in March 2009. However, the technology maturation process may lead to more design changes.

### **Agency Comments**

In commenting on a draft of this assessment, the Navy stated that the AHE program successfully executed Preliminary Design Review (PDR) in October 2004. The program office also completed PDRs for each of the AHE subsystems, to include critical technologies, and documented appropriate risks. The Navy noted that all program risks and associated mitigation plans, including those for critical technologies, were reviewed for PDR. According to the Navy, critical technologies do not currently represent a high risk to the AHE program. Navy officials stated that the program is on schedule and meeting cost and performance objectives.

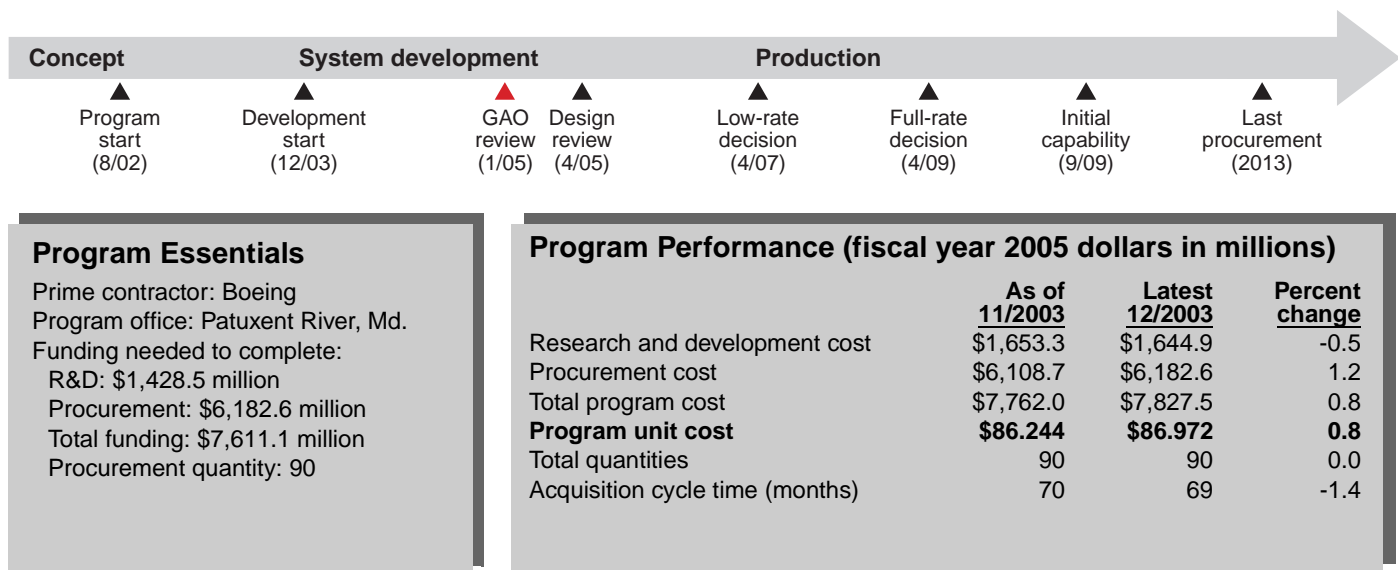
Flight tests of the critical technologies are planned during system design and development. The Navy noted that flight tests will inherently increase the technology readiness levels (TRLs) of the critical technologies. These TRLs will be formally assessed before the production decision in fiscal year 2009.

## EA-18G

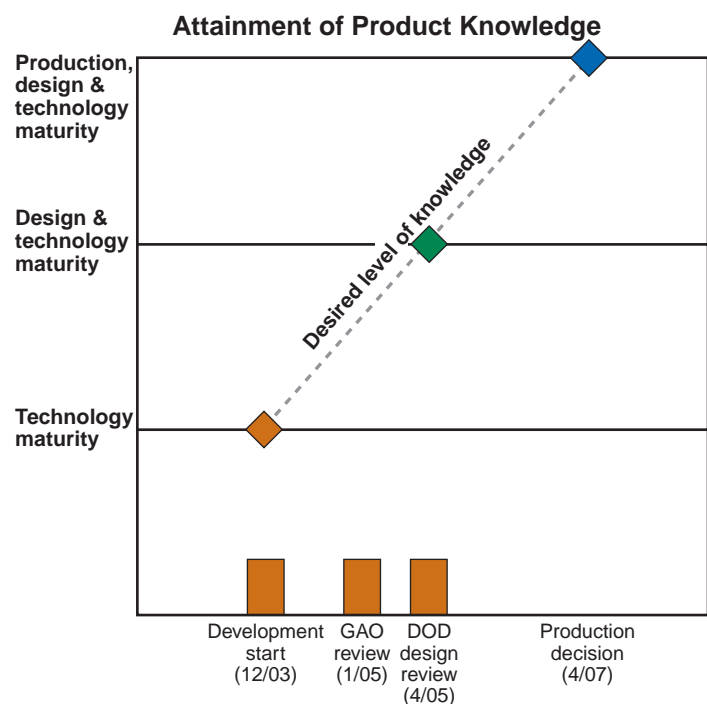
The Navy's EA-18G is an electronic attack aircraft designed to jam enemy radar and communications and conduct electronic warfare as part of a battle group. The program was approved as a replacement for the EA-6B aircraft, and it will integrate its electronic warfare technology and components into the F/A-18F platform. Because of the heavy use of the aging EA-6B aircraft, a large number are being retired due to wear. To prevent a gap in electronic warfighting capabilities, DOD intends to begin fielding the EA-18G in 2009.



Source: F-18 Program Office.



The EA-18G entered system development without demonstrating that its five critical technologies had reached full maturity. Three technologies were very close to maturity, and two technologies have not been demonstrated in the form they will exist on the aircraft. While the EA-18G's critical technologies are similar to mature technologies on the EA-6B and the F/A-18F, integrating them into the EA-18G will involve form and fit challenges. The EA-18G will rely on planned capability upgrades developed for the EA-6B, which could increase program risk. In addition to these challenges, the program also faces risks with software integration. The program office could not project the number of releasable drawings until the design review in April 2005.



## EA-18G Program

### Technology Maturity

None of the EA-18G's five critical technologies are fully mature. While they are similar to the mature technologies found on the EA-6B and the F/A-18F, integrating those technologies on the EA-18G will involve form and fit challenges. Three of the critical technologies, the ALQ-99 pods, the F/A-18F platform, and the tactical terminal system, are approaching full maturity. The remaining two technologies, the receiver system and the communications countermeasures set, are not mature.

The Navy is funding a study to develop a new tactical terminal system, which it hopes to incorporate into the EA-18G to help reduce weight, conserve power, and reduce cooling requirements. According to the program office, similar systems are already in use in DOD. For example, the Special Operations Forces are using a system the size of a credit card, significantly lighter than the current 50-pound system. If the new system is not developed in time for the start of aircraft production, the program plans to use a modified version of the tactical terminal system currently in use on the EA-6B.

Raytheon Systems is developing the communications countermeasures set for the EA-18G, which will be based on a similar system currently used on the C-130J aircraft. Raytheon is expected to begin delivery of the system in January 2005.

### Design Stability

We could not assess the design stability of the EA-18G as the number of releasable drawings is not yet available. The EA-18G Program Office does not expect to have an estimate of the number of design drawings until the design review, currently planned for April 2005. By not having sufficient design drawing information, the program places itself at increased cost and schedule risk.

### Other Program Issues

The EA-18G Program Office plans to build one-third of its aircraft during low-rate initial production due to the need to begin replacing retiring EA-6Bs by 2009. Any problems identified in testing during production could result in costly modifications

to the already produced aircraft. The program office has indicated it may proceed into production even if minor known deficiencies exist.

Because the EA-18G is using the same airframe as the F/A-18F, the program office is conducting a study to determine what impact the increased vibration of the EA-18G will have on the life span of the airframe. The program office also plans to certify the aircraft to land aboard ship at 47,000 pounds, which is 3,000 pounds heavier than the similar F/A-18F aircraft.

The F/A-18E/F aircraft has experienced problems with "wing buffet," which can affect performance. The F/A-18F Program Office has made design changes, which it expects will resolve the issue.

The ALQ-99 pods successfully completed shake testing, which evaluated their ability to handle the increased vibrations of the EA-18G.

The EA-18G program may experience minor cost growth if cuts are made in the number of EA-6Bs that are upgraded because the EA-18G program plans to procure some of the same components as those used in the EA-6B ICAP III upgrade. Decreased purchases by the EA-6B program would increase unit costs of these items, thereby increasing the cost to the EA-18G.

### Agency Comments

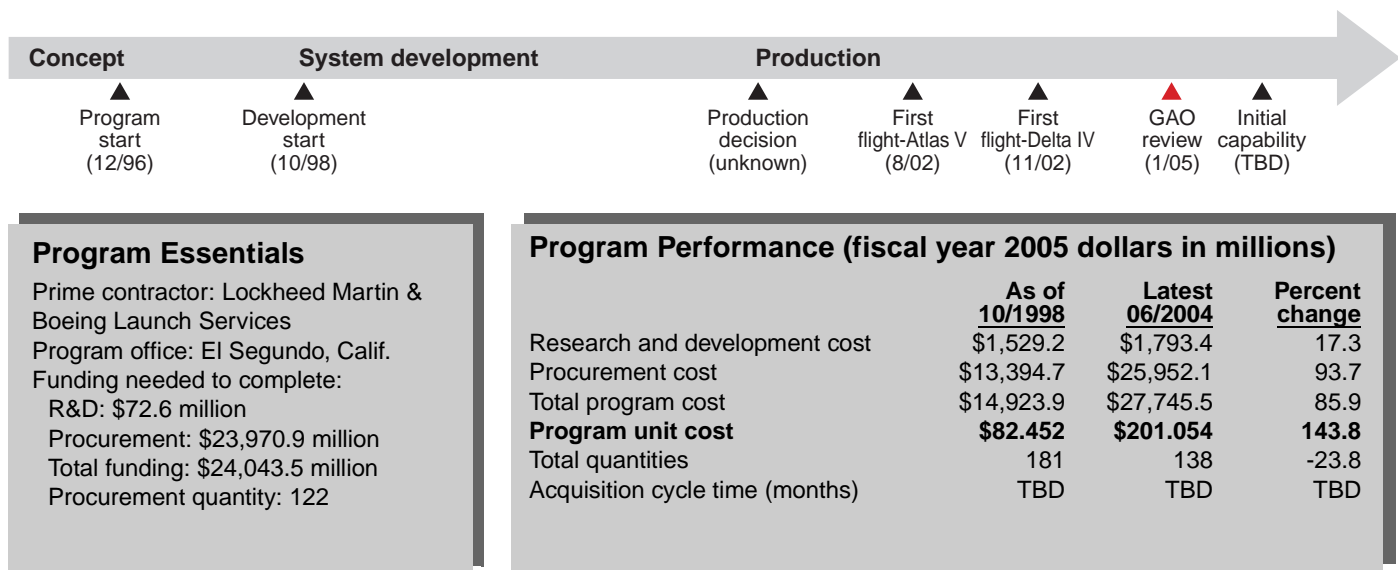
The Navy provided technical comments, which were incorporated as appropriate.

## Evolved Expendable Launch Vehicle (EELV) - Atlas V, Delta IV

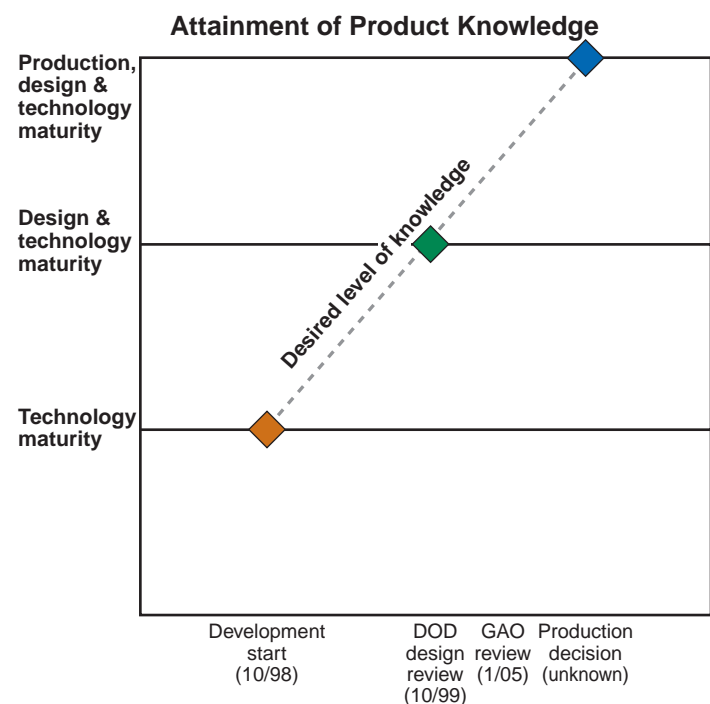
The Air Force's EELV program acquires commercial satellite launch services from two competitive families of launch vehicles—Atlas V and Delta IV. The program is an industry partnership to support and sustain assured access to space and reduce the life-cycle cost of space launches by at least 25 percent over previous systems while meeting the government's launch requirements. Different types of lift vehicles may be used, depending on the particular mission. We assessed both the Atlas V and Delta IV.



Source: (Left) © 2003 ILS/Lockheed Martin; (right) © 2003 The Boeing Company.



Although the EELV Program Office has access to technology, design, and production maturity information, it has not formally contracted for this data because it is acquiring the launch service rather than developing the system itself. To date, seven successful EELV launches have occurred—two government and five commercial. With a history of launch delays, the heavy lift vehicle (HLV) had its first demonstration flight in 2004. The EELV program's total costs have increased about 86 percent due to a decline in the commercial launch market upon which the business case was based.



## **EELV Program**

### **Technology Maturity**

We could not assess the technology maturity of EELV because the Air Force has not formally contracted for information on technology maturity from its contractors.

### **Design Stability**

We could not assess the design stability of EELV because the Air Force has not formally contracted for the information needed to conduct this assessment.

### **Production Maturity**

We could not assess the production maturity of EELV because the Air Force has not formally contracted for information that would facilitate this assessment.

### **Other Program Issues**

The decline in commercial satellite launch needs in the late 1990s resulted in program cost increases and a reduction in the anticipated number of Atlas V and Delta IV launches. Cost increases greater than 25 percent over the program's objective triggered a Nunn-McCurdy breach (see 10 U.S.C. 2433), requiring a review by the Secretary of Defense and a report to Congress. As provided by the law, DOD certified in April 2004 that the program is critical to national security and its cost estimates are reasonable. In conjunction with the certification, the Air Force is updating the 1994 Space Launch Modernization Plan (which examines launch alternatives), and it revised its mission model to reflect a reduction of launch vehicles. Also, the Air Force is reviewing contract structures that could include cost type provisions for the follow-on procurement of EELV services.

The EELV program has continued to experience schedule changes to the Delta IV heavy lift vehicles (HLV). The Delta IV heavy-lift demonstration flight that was planned for July 2004 did not occur until December 2004 and the HLV first operational flight was delayed by 6 months. According to the Air Force, these delays occurred due to a number of factors, including other launch priorities, slips in launch dates for the first three Delta IV missions, modifications to the HLV launch pad, and design problems encountered during launch pad testing. In addition, both contractors are addressing technical

issues related to meeting program requirements. The Boeing Company is addressing a Delta IV issue related to the separation of the payload fairing device (which encloses and protects the payload). Lockheed Martin is dealing with an Atlas V intermediate class booster issue regarding the excessive vibration caused by the noise generated at liftoff.

According to DOD, initiatives are in place to reduce EELV risk and ensure access to space. The initiatives are aimed at critical rocket components, improving the producibility of the upper stage engine, systems engineering processes, and the availability of critical staff and facilities. Related to these initiatives, there are three technical issues that the Air Force is addressing. Parts of the RL-10 upper stage engine are common to both the Delta IV and the Atlas V and an engine flaw could potentially ground both vehicles. However, the Air Force maintains that the RL-10 has flown successfully since the 1960s. Also, the Atlas V continues to rely on the Russian-made RD-180 propulsion technology (though the contractor plans to start building this technology in the United States with a first military launch by 2012). Additionally, until the West Coast launch pad becomes operational in 2005 in time for the first U.S. government need in 2006, the Air Force is limited to launching the Atlas V from its East Coast launch pad.

### **Agency Comments**

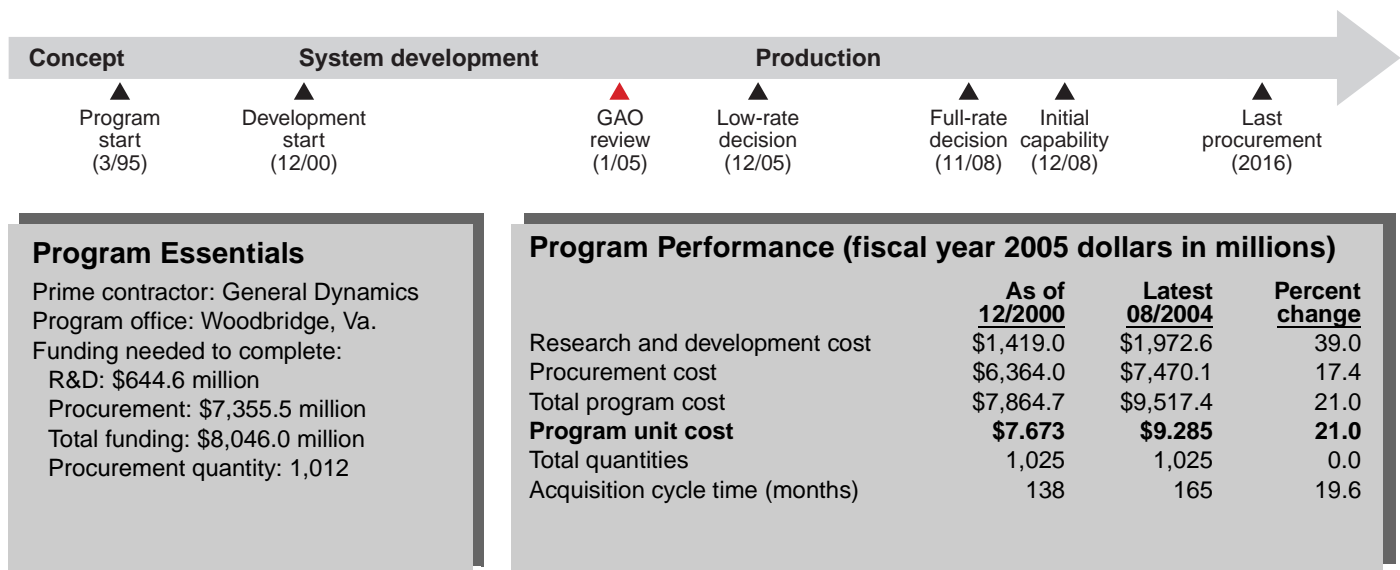
In commenting on a draft of this assessment, the Air Force acknowledged that technology, design, and production maturity data are not required as a deliverable, and therefore it does not have the authority to provide this information. However, daily interaction with both contractors provides insight into the readiness of the launchers as well as the potential for cost increases and schedule issues.

## Expeditionary Fighting Vehicle (EFV)

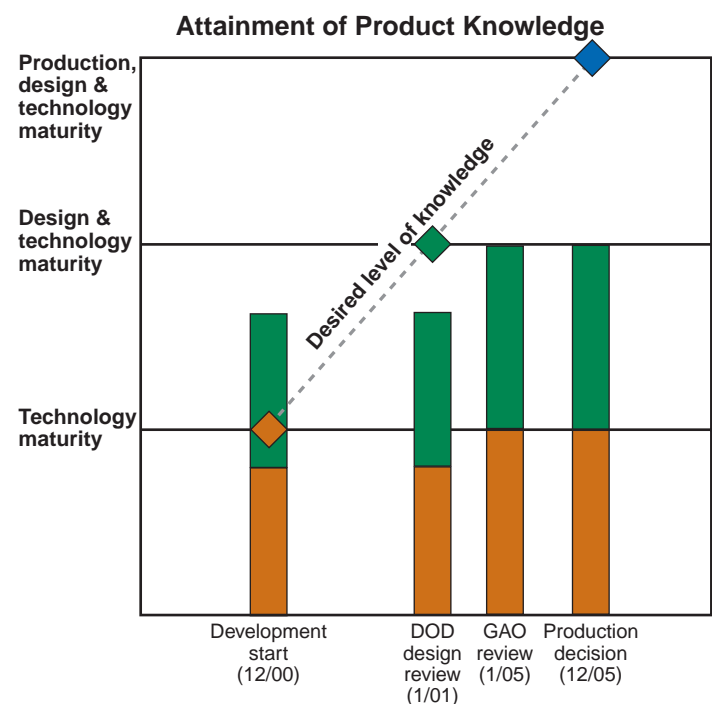
The Marine Corps' EFV (formerly called the Advanced Amphibious Assault Vehicle) is designed to transport troops from ships offshore to their inland destinations at higher speeds and from farther distances than the existing Assault Amphibious Vehicle 7A1 (AAV-7A1). It is designed to be more mobile, lethal, reliable, and effective in all weather conditions. The EFV will have two variants—a troop carrier for 17 combat equipped Marines and 3 crew and a command vehicle to manage combat operations in the field. We assessed both variants.



Source: General Dynamics Land Systems.



The EFV's technology is mature and the design is stable. However, at the start of development, only four out of five critical technologies were mature. The demonstration of the moving map, the last of these technologies, has led to full technology maturation. The design was close to meeting best practice standards at the design review, signifying the design was relatively stable. Early development of fully functional prototypes and other design practices have facilitated design stability. Based on the functional prototyping, the program expects changes to roughly 12 percent of the drawings. The demonstration of production maturity remains a concern because the contractor does not collect statistical process control data.



## EFV Program

### Technology Maturity

All five of the EFV's critical technologies are mature. The moving map navigation technology, which was not mature at the start of product development, was recently demonstrated in an operational environment on the full-up system prototype. The moving map technology provides situational awareness.

### Design Stability

The program has now released all of its drawings for the troop carrier variant. However, 12 percent require design changes to address reliability issues. At the time of critical design review in 2001, 84 percent of the expected drawings had been released, signifying the design was approaching stability. The program is currently seeking to reduce the threshold for the reliability key performance parameter based on a USMC reevaluation of concept of operations. According to program officials, reliability is a moderate risk but may elevate to high risk if the requirement change is not approved. Program officials expect the EFV to meet revised reliability thresholds by initial operational testing in November 2007.

According to the program, recent tests of an improved track and wheel design demonstrated significant improvements in reducing vibration on the vehicle. Program officials estimate that vibration levels have been reduced by up to 50 percent over previous measurements. The new track and wheel design will be incorporated on the vehicles used for the operational assessment in March 2005.

### Production Maturity

The program expects to enter low-rate production in December 2005. It will do so without requiring the contractor to use statistical process controls to demonstrate that the 12 critical processes are producing quality and reliable products. Instead, the contractor plans to have 95 percent of the production tooling and manufacturing processes in place by low-rate production start. These processes are being utilized and refined to build the prototype vehicles. Additionally, the program and the contractor are in planning stages for production readiness reviews that assess production processes, identify any additional critical manufacturing processes, and determine the benefit of using

statistical process controls. Because the final EFV production facility is not ready, the contractor is using the planned manufacturing processes to build prototypes at the development facility. This will provide verification of these manufacturing processes. However, when production moves to the new facility, processes will need to be validated again to ensure they work as expected.

### Other Program Issues

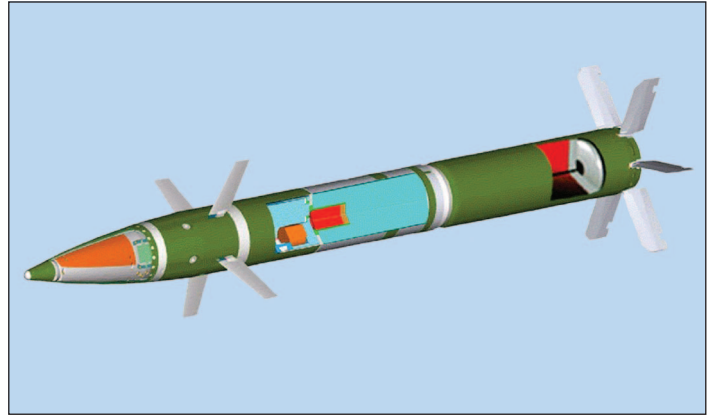
The program tracks a number of entrance criteria for low-rate production and is on track to meet most of those criteria. One key entrance criterion is an operational assessment scheduled for March 2005. The assessment will include the demonstration of a launch and recovery from an amphibious ship; transportation of Marines on water and on land; and negotiation of the vehicle in a 4-foot surf. Another key entrance criterion, demonstration of system reliability, is a moderate risk and may delay low-rate production.

### Agency Comments

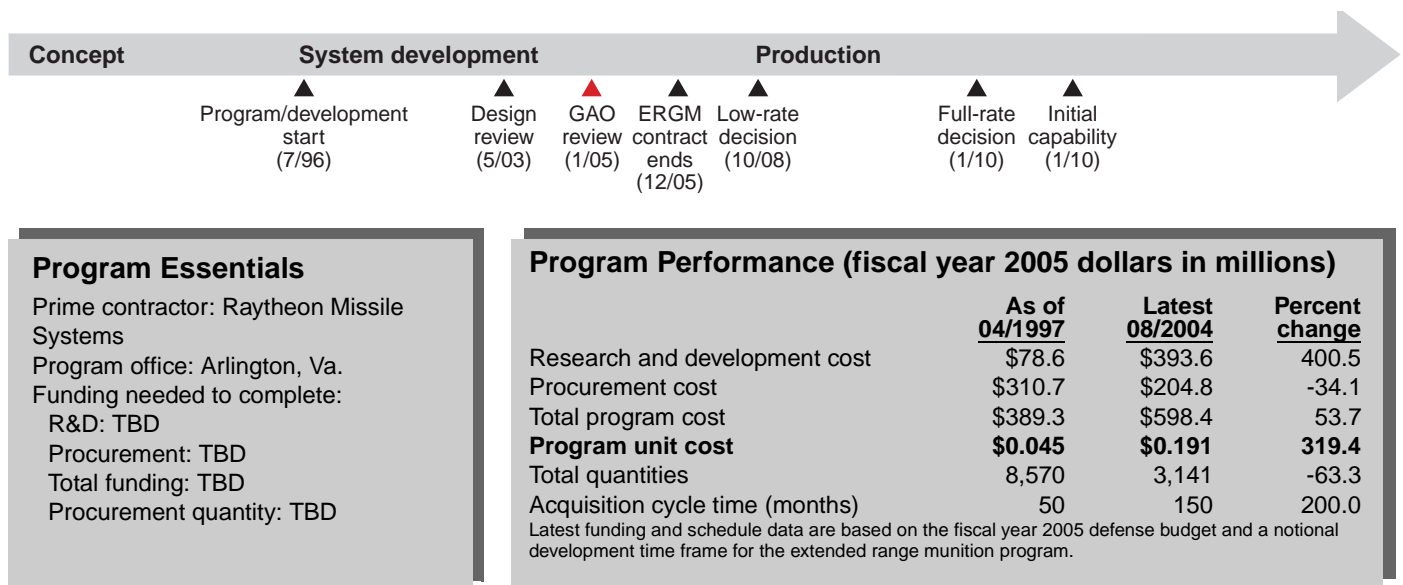
The EFV Program Office was provided an opportunity to comment on a draft of this assessment, but it did not have any comments.

## Extended Range Guided Munition (ERGM)

The Navy's ERGM is a rocket-assisted projectile that is fired from guided missile destroyers. ERGM is one concept the Navy is considering to meet its fire support requirement. ERGM can be guided to targets on land at ranges of between 15 and 50 nautical miles to provide fire support for ground troops. It is expected to offer greater range and accuracy than the Navy's current 13 nautical mile gun range. ERGM required modifications to the 5-inch gun, a new munitions-handling system, and a new fire control system. We assessed the projectile.



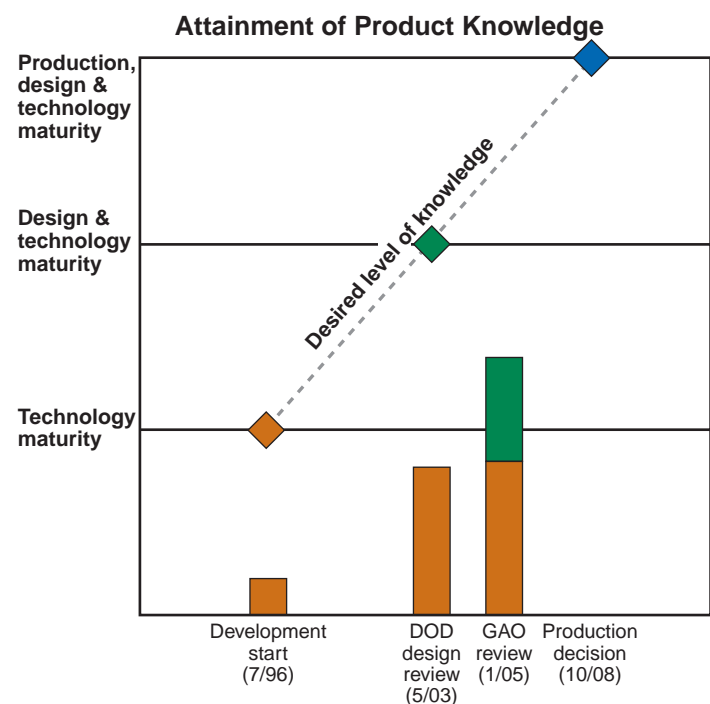
Source: Naval Gunnery Project Office.



### Program Essentials

Prime contractor: Raytheon Missile Systems  
 Program office: Arlington, Va.  
 Funding needed to complete:  
 R&D: TBD  
 Procurement: TBD  
 Total funding: TBD  
 Procurement quantity: TBD

Since our last assessment, the ERGM program has not demonstrated additional technology maturity or design stability. Due to problems with the rocket motor and propelling charge, flight testing was halted, and the program has been unable to demonstrate the maturity of 7 of its 20 critical technologies. The program plans to resume flight testing in February 2005. If that test is successful, four technologies will demonstrate maturity. The program also stated that ERGM's design drawings will not be completed because of limited program funding. Therefore, ERGM will not reach design maturity under Raytheon's current contract. Finally, due to concerns about ERGM's inconsistent test performance and projected unit cost, the Navy plans to recompute the 5-inch guided projectile requirement and restart development by mid-fiscal year 2006. If ERGM is not selected, it will cease to be a program.



## ERGM Program

### Technology Maturity

Thirteen of ERGM's 20 critical technologies are mature. The program has completed development work on six of the seven remaining technologies, but has yet to test them in an operational environment. Program officials currently project that four of the remaining technologies, the tactical telemeter and the three unitary warhead-related technologies, will be demonstrated during a February 2005 flight test. The program's fiscal year 2005 budget request was reduced from \$11.3 million to \$4.5 million, and the program's funds will be exhausted in March 2005. Unless the program receives additional funding, none of the three remaining critical technologies—antijam electronics, safe and arm device and fuze, and data communication interface—will achieve maturity under the current contract since the Navy plans to recompet the 5-inch guided projectile requirement and restart development in early to mid-fiscal year 2006. If the ERGM concept is selected, the program office projects that all ERGM critical technologies would be demonstrated in an operational environment by 2008.

### Design Stability

The program has released approximately 51 percent of its 140 production representative drawings. None of ERGM's production representative engineering drawings were released at its May 2003 design review. Instead, the program conducted this review with less mature drawings and used them to validate the design of the development test rounds. In our March 2004 report, the program office stated that it would have a complete and updated drawing package by October 2004. However, because of a lack of funds and the 5-inch guided projectile competition that will end the current ERGM contract, the contractor will not complete this drawing package. If the ERGM concept is selected, the option exists to complete this drawing package.

### Production Maturity

Since the future of the ERGM concept will not be determined until January 2006, it is unclear whether and when the program will proceed to production. If the ERGM concept is chosen, the current manufacturing plan states the contractor will identify key product characteristics and then determine how to implement statistical process control.

### Other Program Issues

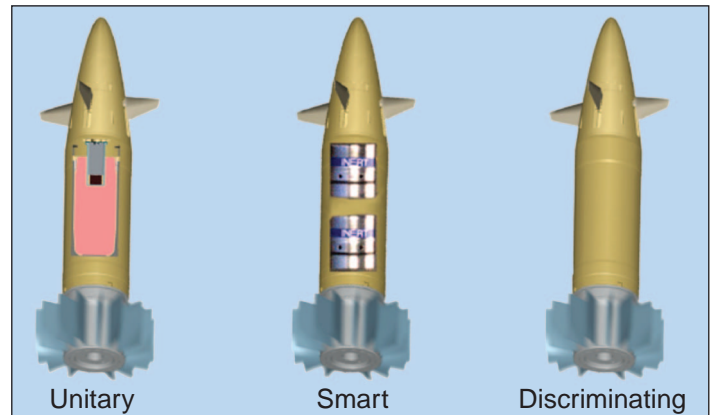
In May 2004, the Navy awarded a contract to ATK to demonstrate an alternative precision-guided munition concept—the Ballistic Trajectory Extended Range Munition (BTERM). BTERM will likely be one of the concepts competing for the new development contract. In fiscal years 2004 and 2005, the Navy budgeted \$35 million for the BTERM effort. The BTERM technology demonstration includes six guided flight tests in 2005. At this point, none of the BTERM critical technologies have reached maturity. However, according to the project office, the six flight tests, if successful, will demonstrate most of BTERM's critical technologies in a relevant or operational environment. Finally, the latest ERGM program cost and schedule estimates do not reflect the potential cost and time needed to complete the 5-inch guided projectile development effort. The Navy is currently considering an acquisition strategy that would start a new development program with a revised program baseline, which could delay initial operational capability until 2011 depending on the maturity of the concept selected. The procurement cost of this new program will likely be much higher than is currently reported for ERGM because the latest cost estimate for the ERGM program is based on the procurement funding available in the future year defense plan, not current inventory requirements.

### Agency Comments

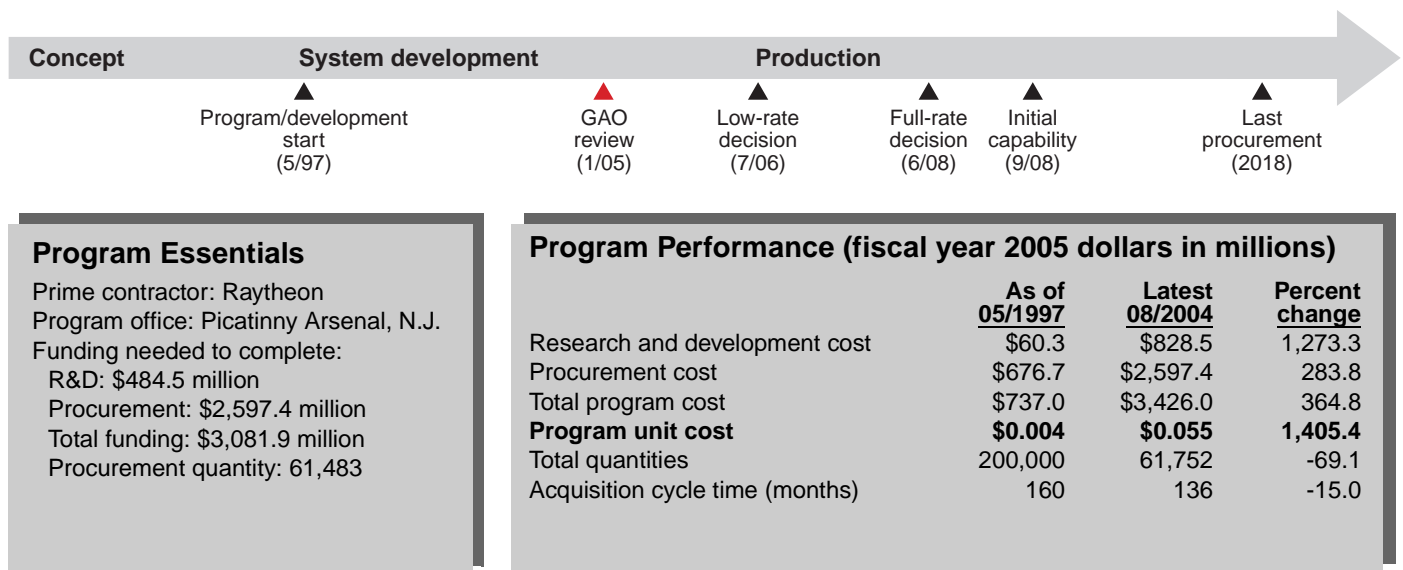
In commenting on a draft of this assessment, the Navy stated that it intends to issue a request for proposal in fiscal year 2005 and select an Extended Range Munition (ERM) development contractor in fiscal year 2006. It will request that the program start the system development phase due to the maturity of guided projectile concepts that could meet ERM requirements. The Navy also stated that research, development, test, and evaluation (RDT&E) funds in fiscal year 2006-2011 will be used for the ERM development effort, resulting in an initial operational capability of no later than fiscal year 2011. Depending upon the maturity of the concept selected, development could end as early as fiscal year 2008 with a fiscal year 2009 initial operational capability. In this case, fiscal year 2006-2008 RDT&E funding (about \$58.4 million) would be used to complete the program and fiscal year 2009-2011 funding (about \$87.3 million) would support spiral development and/or product improvement initiatives.

## Excalibur Precision Guided Extended Range Artillery Projectile

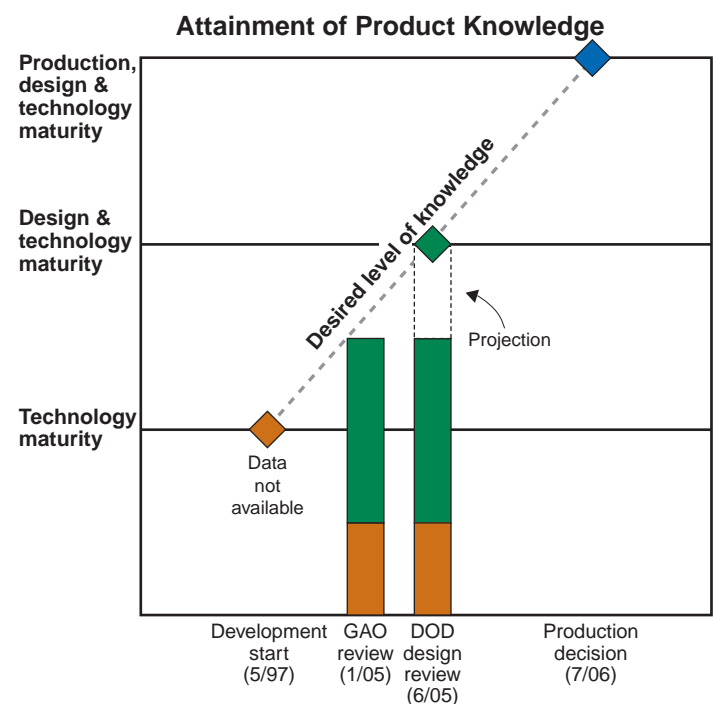
The Army's Excalibur is a family of global positioning system-based, fire-and-forget, 155-mm cannon artillery precision munitions. It is intended to improve the accuracy and range of cannon artillery. Also, the Excalibur's near vertical angle of fall is intended to reduce the collateral damage area around the intended target, making it more effective in urban environments than the current artillery projectiles. The Future Combat Systems' non-line-of-sight cannon requires the Excalibur to meet its required range.



Source: U.S. Army.



The Excalibur program's critical technologies are not fully mature, even though product development began over 7 years ago. Program officials expect to have technology maturity by June 2005. The program has achieved design stability. Currently, almost all of the Excalibur drawings are completed and could be released to manufacturing. However, the Excalibur is undergoing testing that may lead to design changes. The program has encountered a number of challenges since development began, including a decrease in planned quantities, a relocation of the contractor's plant, early limited funding, technical problems, and changes in program requirements. It merged with the Trajectory Correctable Munition program in 2002.



## Excalibur Program

### Technology Maturity

None of the Excalibur's three critical technologies—the guidance control system, the airframe, or the warhead—are fully mature. According to program officials, all three have been demonstrated in a relevant environment, and they are expected to reach full maturity before the design review in June 2005. The warhead was not considered a critical technology in 1997 because the Excalibur design called for a warhead that was under production for other munitions. At the Army's direction, the program has undertaken development of a different warhead that is currently undergoing testing.

### Design Stability

The most recent program restructure divided the design review into two reviews. The first, scheduled for June 2005, freezes the first article test design and the second, scheduled for the first quarter of fiscal year 2006, freezes the production design. The program recently completed an Early Fielding Technical Data Package review of the design drawings. The review found that about 97 percent of the Excalibur engineering drawings are complete and releasable to manufacturing. The program office plans to have all of the drawings complete by the June 2005 design review. The Excalibur has to complete safety and other testing before it is ready for production. This testing could lead to design changes.

### Other Program Issues

The program has gone through many changes since the beginning of product development in May 1997. It was almost immediately restructured due to limited funding, and it was restructured again in 2001. The program was again restructured and merged with a joint Swedish/U.S. program known as the Trajectory Correctable Munition. This merger has helped the Excalibur deal with design challenges, including issues related to its original folding fin design. In May 2002, due to the cancellation of the Crusader, the Army directed the restructure of the program to include the Future Combat Systems' non-line-of-sight cannon. In December 2002, the Acting Under Secretary of Defense (Acquisition, Technology, and Logistics) approved an early fielding plan for the unitary version. The plan currently includes developing

the unitary version of the Excalibur in three spirals. In the first spiral, the projectile would meet its requirements for accuracy in a nonjammed environment and lethality and would be available for fielding to Joint Lightweight 155mm cannon in September 2006. In the second spiral, the projectile would be improved to meet its requirements for accuracy in a jammed environment and reliability and would be available for fielding to the Future Combat Systems' non-line-of-sight cannon in September 2008. Finally, in the third spiral, the projectile would be improved to meet its range requirement and would be available for fielding to all systems in late fiscal year 2011.

The net effect of these changes has been to increase the program's schedule and to substantially decrease planned procurement quantities. As a result, the program's overall costs and unit costs have dramatically increased.

### Agency Comments

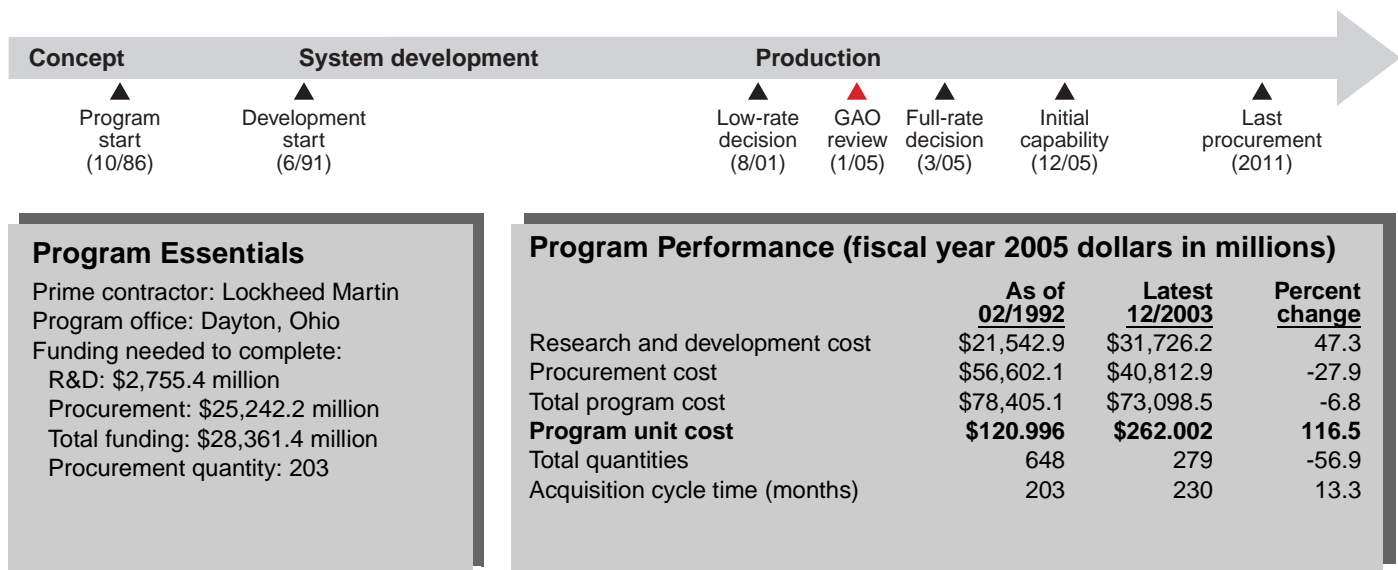
The Army provided technical comments, which were incorporated as appropriate.

## F/A-22 Raptor

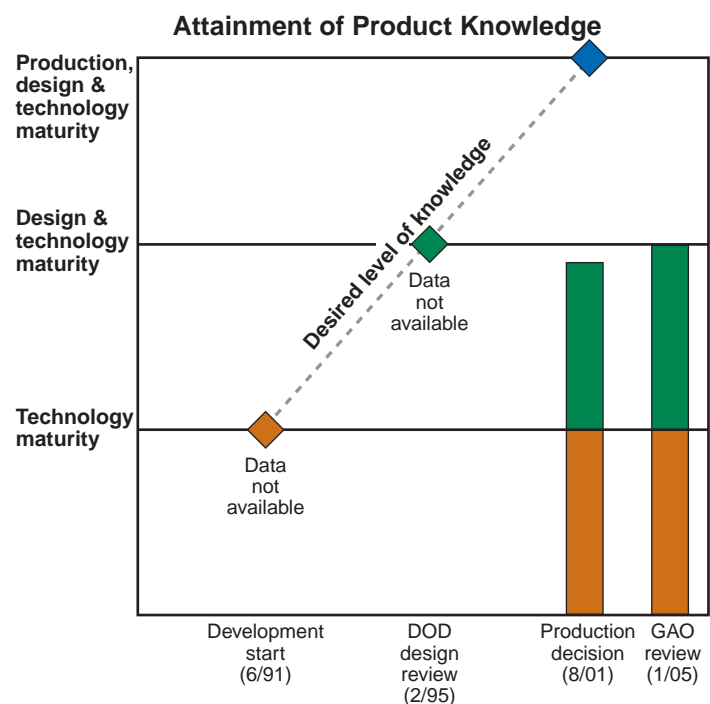
The Air Force's F/A-22, originally planned to be an air superiority fighter, will also have air-to-ground attack capability. It is being designed with advanced features, such as stealth characteristics, to make it less detectable to adversaries and capable of high speeds for long ranges. It also has integrated aviation electronics (avionics) designed to greatly improve pilots' awareness of the situation surrounding them. It is designed to replace the Air Force's F-15 aircraft.



Source: F/A-22 System Program Office.



The F/A-22 entered production without ensuring that production processes were in control. The Air Force expects to have about 27 percent of the aircraft on contract prior to the full-rate decision in March 2005, yet quality issues remain. For example, the F/A-22 has not achieved important reliability goals and some components, like the canopies, are not lasting as long as expected. Technology and design matured late in the program and have contributed to numerous problems. Avionics problems were discovered late in development, which resulted in large cost increases and caused testing delays. The potential for further cost increases and schedule delays exists until initial operational testing and follow-on testing are completed. Additionally, \$7 billion in cost reductions has to be achieved to keep cost growth within the congressionally mandated production cost limitation.



## **F/A-22 Raptor Program**

### **Technology Maturity**

The three critical F/A-22 technologies (supercruise, stealth, and integrated avionics) appear to be mature. However, two of these technologies, the integrated avionics and stealth, did not mature until several years after the start of development. Integrated avionics have been a source of major problems, delaying developmental testing and the start of initial operational testing. Since 1997 the costs of avionics have increased by over \$801 million and problems discovered late in the program were the major contributor. In April 2004, the Air Force began initial operational test and evaluation after reporting that these problems were corrected.

### **Design Stability**

The F/A-22 design is essentially complete, but it matured slowly, taking over 3 years beyond the critical design review to meet best practice standards. The late drawing release contributed to parts shortages, work performed out of sequence, delayed flight testing and increased costs. Design changes resulted from flight and structural tests. For example, problems with excessive movement of the vertical tails and overheating problems in the fuselage and engine bay required design modifications. The Air Force completed development testing in December 2004 and operational testing in November 2004. The Air Force is in the process of evaluating the results of operational testing. The results of this evaluation could result in additional design changes.

### **Production Maturity**

The program office stopped collecting process control information in November 2000. The contractor estimated that nearly half of the key processes had reached a marginal level of control, but not up to best practice standards. The Air Force has 67 production aircraft on contract. The Air Force relies on the contractor's quality system to verify manufacturing and performance requirements are being met. However, the Air Force has not demonstrated the F/A-22 can achieve its reliability goal of 3 hours mean time between maintenance. It does not expect to achieve this goal until 2008 when most of the aircraft will have already been bought. Best practices call for meeting reliability requirements before entering production. As of mid-October 2004, the Air Force had only

demonstrated about 22 percent of the reliability required.

### **Other Program Issues**

The Air Force is counting on future cost reduction plans to offset estimated cost growth and enable the program to meet the latest production cost estimate. If these cost reduction initiatives are not achieved as planned, production costs could increase.

The Integrated Maintenance Information System (IMIS), a paperless computerized maintenance system, is used by the Air Force to maintain the F/A-22. The system collects and analyzes problem data and develops a maintenance solution. The system has not functioned properly causing unnecessary maintenance actions. This has affected the Air Force's ability to fly the test aircraft on schedule. The Air Force installed new software in February 2004 to address many of the errors generated by IMIS and uncovered additional errors. According to the Air Force, these problems were resolved in July 2004. In November 2004, the Air Force upgraded IMIS to a commercially supportable operating platform and database that added new functionality such as wireless connectivity.

### **Agency Comments**

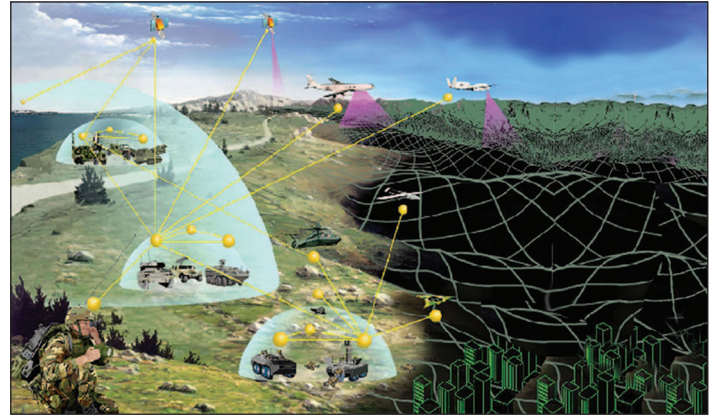
In commenting on a draft of this assessment, the Air Force provided technical comments, which were incorporated as appropriate. The Air Force also stated that, in coordination with the DCMA and contractor teammates, the program is aggressively pursuing cost reduction initiatives to meet cost goals. It stated that these goals represent a significant reduction in per aircraft cost and include substantial improvements to production by the primes and subcontractors. The Air Force disagreed, however, with the value we reported in our draft assessment. It stated that the initiatives total \$2.5 billion. The Air Force also indicated that the reliability of the F/A-22, while maturing, is already comparable to legacy Air Force fighter aircraft while delivering a required combat capability that cannot be achieved by legacy platforms.

### **GAO Comments**

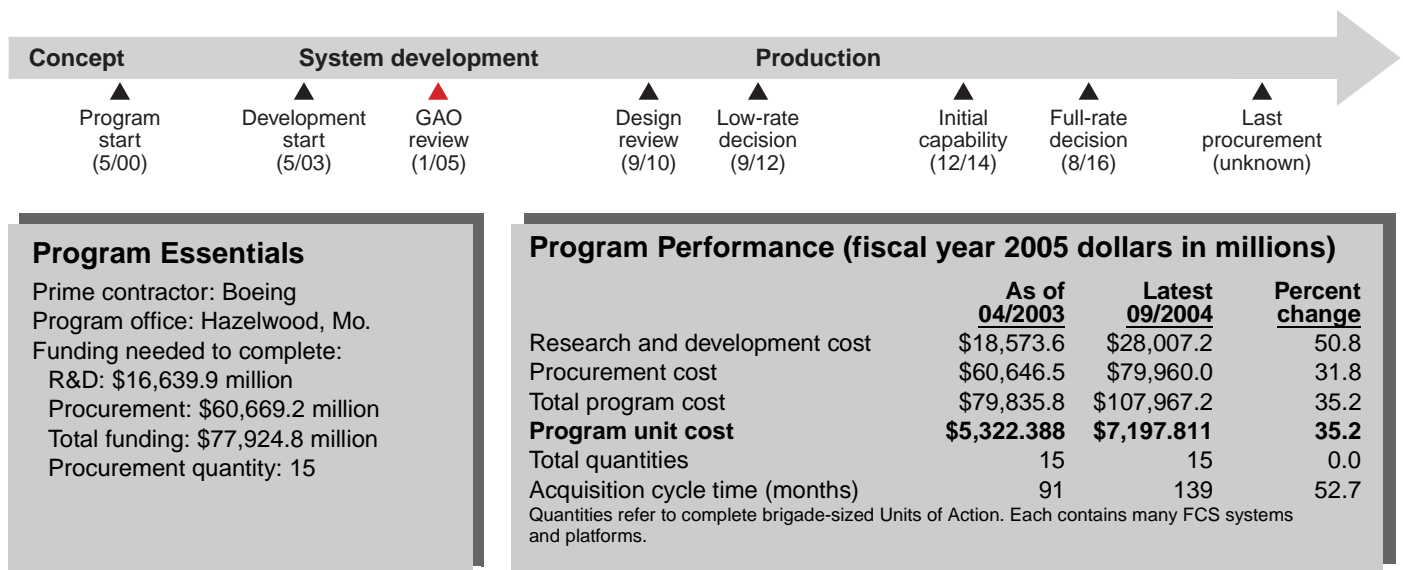
We reviewed the Air Force's comments concerning projected production cost reduction savings and determined that the Air Force will have to reduce the current production estimate by approximately \$7 billion to execute the program within a congressional mandated cost cap.

## Future Combat Systems (FCS)

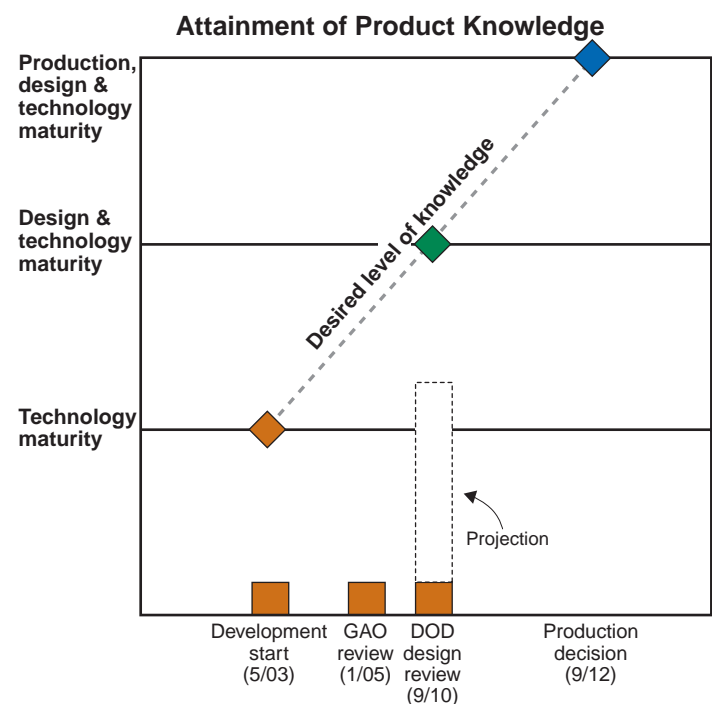
The FCS, a program that will equip the Army's new transformational modular combat brigades, consists of a family of systems composed of advanced, networked combat and sustainment systems, unmanned ground and air vehicles, and unattended sensors and munitions. Within a system-of-systems architecture, the first increment of the FCS features 18 major systems and other enabling systems along with an overarching network for information superiority and survivability.



Source: Program Manager, Unit of Action, U.S. Army.



The FCS program began a major restructuring in July 2004, which delays fielding 4 years, until 2014, and spirals various FCS technologies to the current force. The restructuring increased the priority for developing and demonstrating the FCS network. The program also continues refining requirements. In some cases, the Army has decided to use different technologies, which are less mature than the original technologies. The program expects all of its 54 critical technologies to be mature by the end of fiscal year 2008. Technology maturation will continue throughout system development, with an associated increase in the risk of cost growth and schedule delays. Since the FCS will dominate Army investment accounts over the next decade, cost growth and schedule delays could affect all Army acquisitions.



## **FCS Program**

### **Technology Maturity**

One of the FCS program's 54 critical technologies is currently mature. Overall, the program's current technology maturity is slightly less than it was in May 2003 when the program began development.

The program is not appropriately applying best practices to maturing its critical technologies. It considers technical risk acceptable as long as it can estimate that the technologies will be demonstrated in a relevant environment before design review. Also, it does not consistently include form or fit in technology maturation because it views sizing the technology as an integration risk, not a technology risk. In addition, the program could assess a technology as mature simply because it is part of another program. For example, it assesses the maturity of the technologies enabling the Active Protection System as mature, even though the Army is developing the system for a current combat vehicle that is much larger than the FCS vehicles. The technologies will need to be reduced in size before the system can be incorporated into the FCS vehicles. Overall, the program must continue to mature its technologies while developing the FCS.

In some cases, as the FCS requirements are refined, the Army has decided to use different technologies that are less mature than the original technologies. For example, in February 2004, the program assessed the maturity of ground-to-air combat identification as fully mature primarily because similar identification systems were readily available in air defense systems. In September 2004, however, it reduced the technology's maturity because it refined the FCS requirements and determined that in order to provide required interoperability with NATO systems, the program would have to use an operating mode that required the development of a new interrogator. As a result, it assessed the technology as very immature.

### **Design Stability**

The program estimates that 80 percent of its 42,750 drawings will be released by the design review scheduled for September 2010.

### **Other Program Issues**

The FCS program began a major restructuring in July 2004, which delays fielding an initial FCS capability until 2014, 48 months later than planned. The revised strategy helps meet the needs of an Army at war by making \$9 billion available for investment in future capabilities for the current force, which include FCS technologies that are expected to be transitioned to the current force between 2008 and 2014. It also increases the priority of development and demonstration of the FCS network and system-of-systems architecture along with munitions, sensors, and unmanned vehicles.

The concept of a modular FCS equipped brigade-sized combat unit, known as a Unit of Action, represents a major departure in the way the Army has conducted combat operations and is a major part of the Army's transformation efforts. To successfully develop the FCS, the Army faces a number of technological and programmatic challenges, including equipping Units of Action with a common family of networked vehicles and other systems. These vehicles and systems are expected to be a fraction of the weight of existing heavy fighting vehicles in order to improve transportability such as being airlifted by a C-130 transport.

### **Agency Comments**

The Army provided technical comments, which were incorporated as appropriate. In addition, it considers technical risk acceptable as long as it can estimate that the technologies would be demonstrated in a relevant environment before design review. The restructured FCS program also includes a process for periodically spiraling out technologies to the current force as they reach acceptable levels of maturity. Additional efforts to mature these technologies will continue as needed under the main program. The Army believes this approach will ensure that all technologies are proven before fielding of full FCS-equipped Units of Action. Finally, the Army noted that, in addressing transportability challenges, the FCS program will continue to develop and analyze alternative technical approaches to find the design solution that best meets the broad spectrum of user needs.

### **GAO Comments**

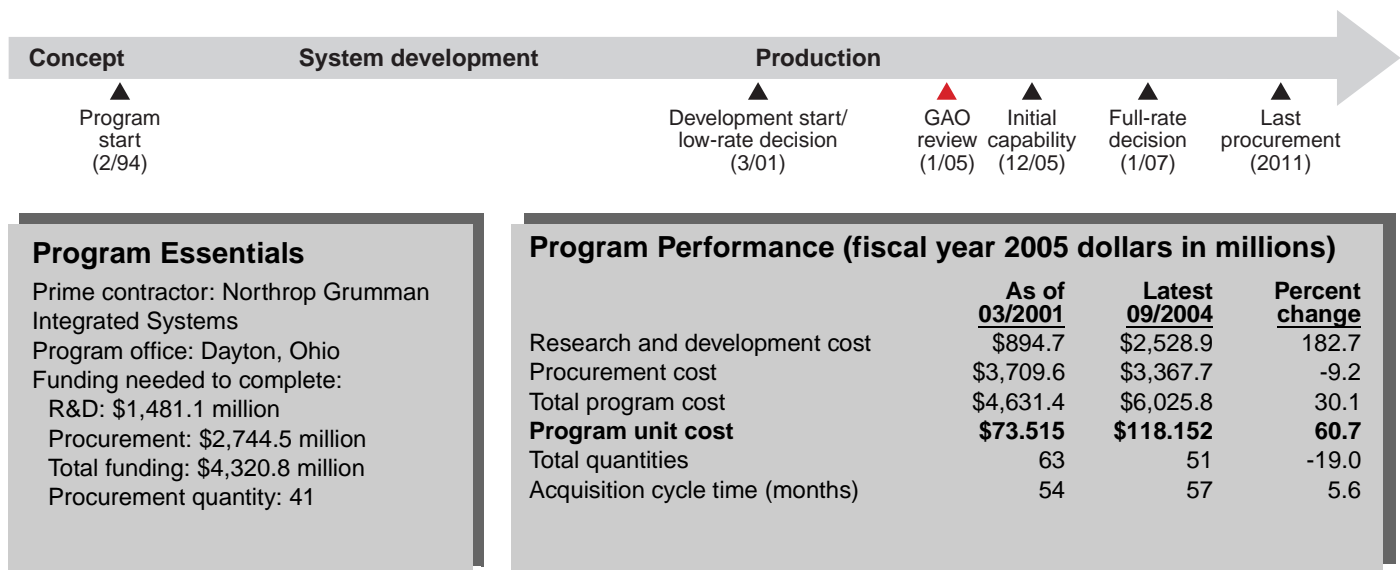
The Army is holding FCS technologies to a lower maturity standard than best practices and DOD policy calls for. This increases the risk of program cost growth and schedule delays.

## Global Hawk Unmanned Aerial Vehicle

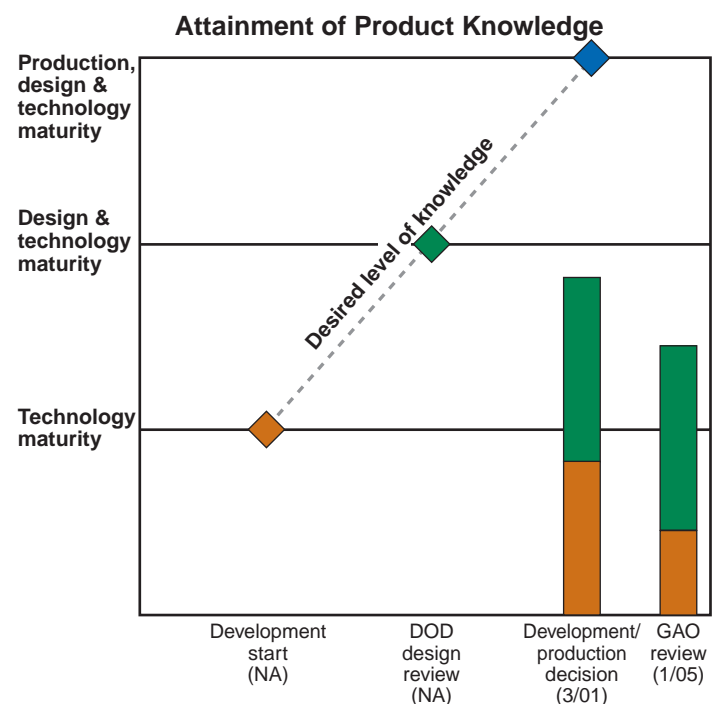
The Air Force's Global Hawk system is a high altitude, long endurance unmanned aerial vehicle with integrated sensors and ground stations providing intelligence, surveillance, and reconnaissance capabilities. After a successful technology demonstration, the system entered development and limited production in March 2001. Considered a transformational system, the program was restructured twice in 2002 to acquire 7 air vehicles similar to the original demonstrators (the RQ-4A) and 44 of a new, larger, and more capable model (the RQ-4B).



Source: Northrop Grumman Corporation.



Key product knowledge on Global Hawk is now less than it was in March 2001 due to the 2002 program restructurings. Officials had planned to first produce systems very similar to technology demonstrators and then slowly develop and acquire more advanced systems. Technology maturity and design stability approached best practice standards for this plan. However, program restructurings accelerated deliveries, overlapped development and production schedules, and added the new, larger air vehicle with advanced sensors. These actions increased development and program unit costs. While the platform design is fairly mature, production of the new air vehicle began with advanced sensor technologies still immature and operational tests not planned until much later. Production maturity cannot be assessed using knowledge-based criteria because statistical process control data are not used.



## Global Hawk Program

### Technology Maturity

Five of 14 critical technologies associated with the Global Hawk system are mature, 3 technologies are approaching maturity, and 6 are less mature. Three of the mature technologies are uniquely associated with the RQ-4A. Two of the 11 RQ-4B's critical technologies are mature—one more than last year. The less mature technologies include the airborne signals intelligence payload and the multiplatform radar technology insertion program. These desired capabilities largely drove the decision to develop and acquire the new RQ-4B air vehicles, which can carry 50 percent more payload than the original model, the RQ-4A.

Production of the first RQ-4B began in July 2004. Integrating and testing these advanced sensors on the air vehicle will not be completed until late in the program when most of the fleet will already have been bought. There is risk that the sensor technologies and final designs may not meet the space, weight, and power limitations of the RQ-4B, resulting in extended development times, costly reworks, or diminished capabilities. The airborne signals intelligence payload currently exceeds its weight allocation, and the power requirements for the multiplatform radar requirements near the RQ-4B's limit.

### Design Stability

The RQ-4A design is stable, and 75 percent of RQ-4B engineering drawings were completed by the time of its design review in April 2004. By late fiscal year 2004, over 90 percent of the engineering drawings were completed. However, the Air Force has not built a prototype of the RQ-4B to demonstrate a stable design and has not established a reliability growth plan prior to initiating production—both characteristics of best practices used to assure design maturity. Additionally, the Air Force plans to buy almost half the fleet before it completes initial operational test and evaluation to verify the air vehicle design works as required. This increases the potential that testing may identify a need to redesign and retrofit aircraft.

### Production Maturity

Although production experience and lessons learned on the RQ-4A will benefit the RQ-4B program, the new model requires different and more complex

manufacturing processes and tooling than the original model. Officials have not implemented, and do not plan to implement, a comprehensive statistical process control program to demonstrate that new manufacturing processes are in control and capable of meeting cost, schedule, and quality targets. Officials have started to identify critical manufacturing processes and will continue to collect performance data such as defect and rework rates to measure product quality. There are continuing concerns about the quality and timeliness of several key subcontractors, which negatively affect cost and schedule of both design and production work. We note that the acceptance of the second production RQ-4A was delayed due to defects and flight deficiencies.

### Other Program Issues

Restructuring the Global Hawk program has accelerated planned deliveries of advanced capabilities and made development, test, and production cycles highly concurrent. Cost increases, schedule slips, and performance trade-offs have already occurred. We recently reported that slowing down production to enable closing the gaps in product knowledge and operationally testing the aircraft should be considered.

### Agency Comments

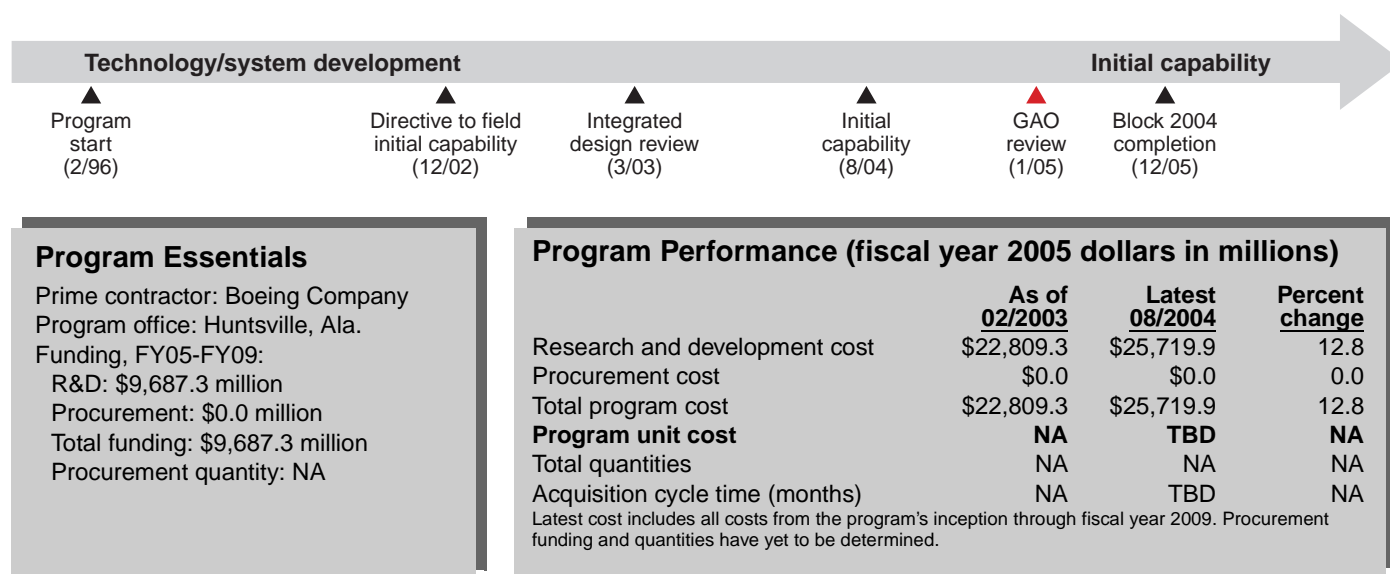
In commenting on a draft of this assessment, the Air Force stated that our knowledge-based criteria do not effectively assess Global Hawk's evolutionary acquisition strategy. It stated that Global Hawk's spiral approach fosters efficiency, flexibility, and innovation and includes the controls essential to manage program risk and achieve effective program results. The Air Force further noted that the Global Hawk program is managing development risks as it migrates from the RQ-4A to the larger, multiple-intelligence RQ-4B configuration. It noted that the RQ-4B is an evolutionary design change, built upon the successful RQ-4A design, years of extensive testing, and over 5,000 RQ-4A flight hours, and also stated that establishing accurate RQ-4B size, weight, and power constraints provides accurate design requirements for development of advanced sensors, further reducing future risk. The Air Force further commented that by using concurrent development and production processes, the Global Hawk program plans to achieve initial operational capability approximately 5 years after program initiation, fielding greater capability than initially planned.

## Ground-Based Midcourse Defense (GMD)

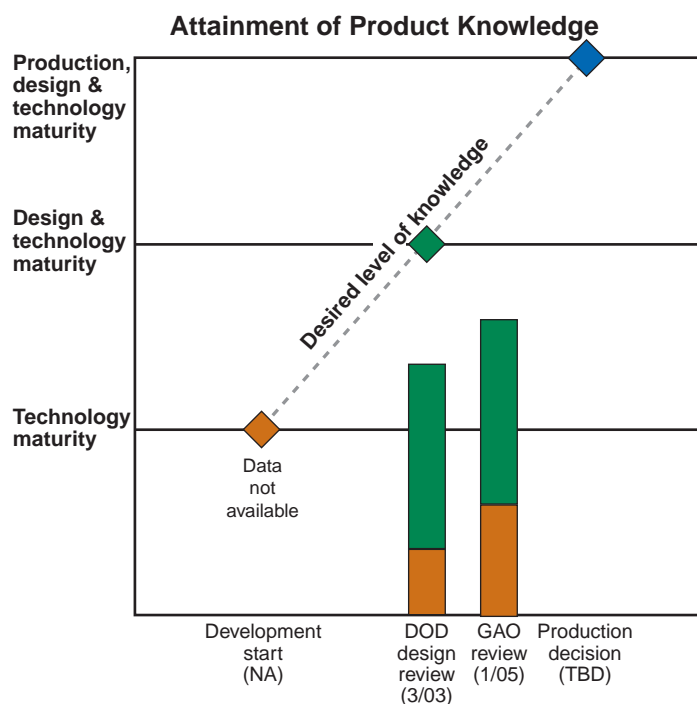
MDA's GMD element is being developed in incremental, capability-based blocks to defend the United States against limited long-range ballistic missile attacks. The first block consists of a collection of radars and an interceptor—a three-stage booster and an exoatmospheric kill vehicle (EKV)—integrated by a central control system that formulates battle plans and directs the operation of GMD components. We assessed all technologies critical to the Block 2004 GMD element, but only the design and production maturity of the interceptor.



Source: Department of Defense.



Three of GMD's 10 critical technologies were fully mature, and its design seemed stable in September 2004 when MDA placed five ground-based interceptors in silos for the initial capability. The remaining technologies were nearing full maturity. However, there is a risk that design changes could occur during Block 2004 because a solution to a technical problem in the kill vehicle has not been proved in flight tests and additional problems could be identified during the flight tests scheduled to occur before the end of the block. Although MDA has not made a formal production decision, it is currently producing hardware for operational use. We could not, however, assess the stability of MDA's production processes as the program is not collecting statistical data on its production processes.



## **GMD Program**

### **Technology Maturity**

Program officials estimate that 3 of GMD's 10 critical technologies are mature: fire control software, the EKV's infrared seeker, and the Orbital Sciences Corporation (OSC) booster. The remaining seven technologies are nearing maturity. These technologies are the Lockheed Martin BV+ booster; Sea-based X-Band radar; Cobra Dane radar; Beale radar; EKV on-board discrimination; EKV guidance, navigation, and control subsystem; and the in-flight interceptor communications system. The program expected to demonstrate 3 of these technologies by the end of fiscal year 2004, but flight test delays prevented the demonstrations. However, program officials expect that the maturity of all 7 technologies will be demonstrated before the end of Block 2004.

### **Design Stability**

The Block 2004 ground-based interceptor design is stable with 100 percent of its drawings released to manufacturing. The ongoing effort to mature critical technologies and solve an ongoing engineering problem, however, may lead to more design changes.

### **Production Maturity**

Officials have not made an official production decision, although they are delivering interceptors for the Block 2004 emergency capability. We could not assess the production maturity of these interceptors because the program is not collecting statistical control data on the production process. According to program officials, data are not tracked because the current quantities of GMD component hardware are small. Instead, the GMD element measures production capability and maturity with a monthly evaluation process that assesses critical manufacturing indicators for both readiness and execution.

To reduce program risk, MDA is following a dual booster strategy, developing the BV+ and the OSC boosters, each of which has a different design. Although this strategy offers two different capabilities and has helped to mitigate production risks, MDA has experienced ongoing problems with the BV+ booster. After an explosion at the facility that mixes propellant for the BV+ booster motors, the facility's contractor ceased operations.

A new contract has been awarded for the production of the BV+ 2nd and 3rd stage motors. MDA hopes to restart manufacturing in fiscal year 2005. Therefore, all Block 2004 interceptors will use the OSC booster.

EKV and booster delivery is on schedule for the December 2005 initial capability. MDA delivered 5 interceptors for initial defensive operations by September 2004, and it plans to have a total of 18 on alert by December 2005. MDA originally planned to have 20 interceptors by this time; however, two of these interceptors were later designated as test assets.

### **Other Program Issues**

Increased cost of the EKV and the explosions at the BV+ propellant-mixing facility were leading causes of \$175 million in GMD cost growth during fiscal year 2004. To avoid a delay in fielding the initial defensive operation on September 30, 2004, MDA funded the cost overrun by having other groups within MDA perform some tasks that GMD was budgeted to complete.

### **Agency Comments**

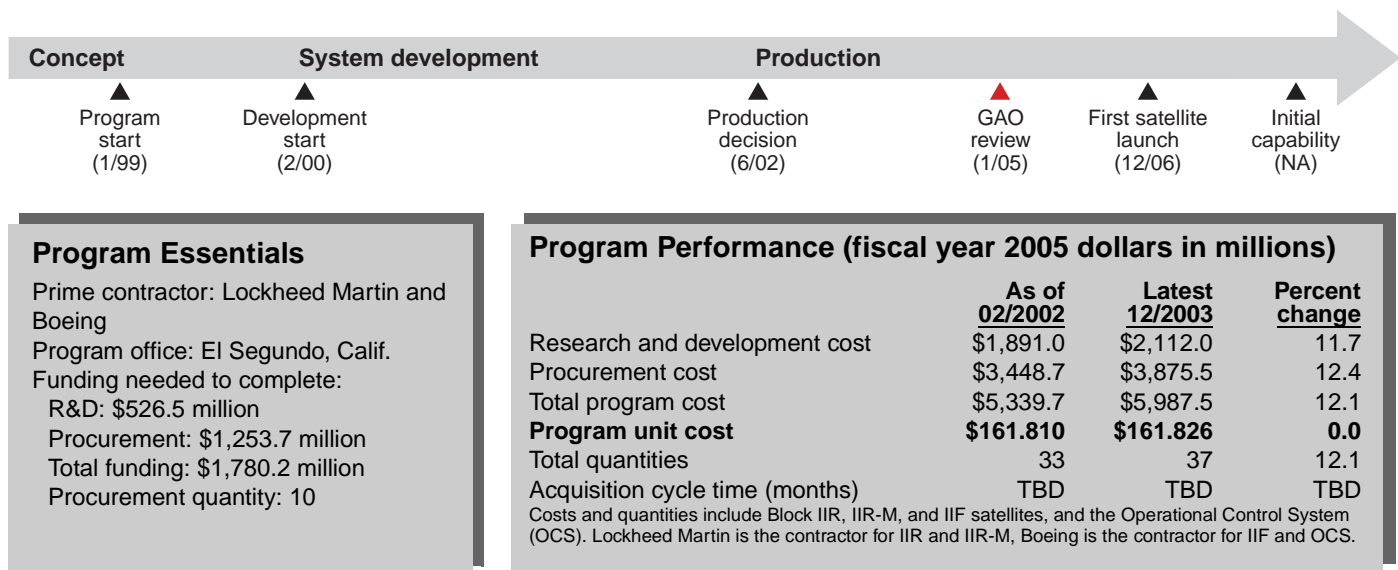
In commenting on a draft of this assessment, MDA stated that a formal production decision is not anticipated or planned in the GMD acquisition approach. It emphasized that it is not feasible to collect data on most GMD production processes due to the extremely low quantities of system hardware being procured, but statistical data are collected and available on those subsystems/parts produced in sufficient volume. It also pointed out that ongoing efforts to mature critical technologies and solve technical problems are an inherent part of the capability-based acquisition/block development approach and that design changes are to be expected as the system is evolved through subsequent blocks. Technical comments were also provided and incorporated as appropriate.

## Navstar Global Positioning System (GPS) II Modernized Space/OCS

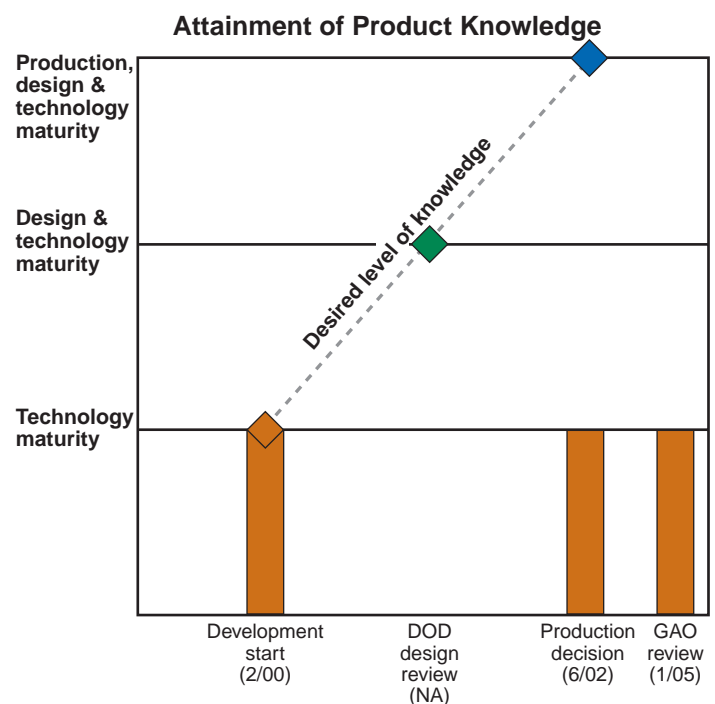
GPS is an Air Force-led joint program with the Army, Navy, Department of Transportation, National Geo-Spatial Intelligence Agency, United Kingdom, and Australia. This space-based radio-positioning system nominally consists of a 24-satellite constellation providing navigation and timing data to military and civilian users worldwide. In 2000, Congress approved the modernization of Block IIR and Block IIF satellites. In addition to satellites, GPS includes a control system and receiver units. We focused our review on the Block IIF.



Source: Navstar GPS Joint Program Office, Space and Missile Systems Center.



According to the program office, the Block IIF technologies are mature. Since the start of the GPS program in 1973, GPS satellites have been modernized in blocks with the newer blocks providing additional capabilities and benefits. The GPS II modernization effort required new technology for the atomic clocks on the IIF satellites, and this technology has been tested in space on IIR satellites. However, the contractor was not required to provide data on design drawings and statistical process control techniques are not being used to monitor production. As a result, design stability and production maturity could not be assessed.



## GPS Block II Modernization Program

### Technology Maturity

The only new critical technology on the Block IIF satellites, the space-qualified atomic frequency standards, was tested in space on Block IIR satellites, and it is considered mature.

### Design Stability

We could not assess design stability because the Block IIF contract does not require that design drawings be delivered to DOD. However, the program office assesses design maturity by reviewing contractor development testing, participating in technical interchange meetings and periodic program reviews, and conducting contractor development process and configuration audits.

### Production Maturity

We could not assess production maturity because the contractor does not collect statistical process control data. However, the program office reviews earned value management reports, integrated master schedules, and test dates as a means of monitoring the contractors' production efforts.

### Other Program Issues

The current Block IIF contract calls for the procurement of 12 satellites. The Air Force estimated that this number would be sufficient for constellation sustainment until the launch of the first GPS III satellite, scheduled for 2010. However, in fiscal year 2003, the Air Force restructured the GPS III launch schedule and delayed the first launch to 2012. Consequently, four additional satellites will need to be acquired to sustain the GPS constellation due to this delay. To build these additional satellites, several subsystems would require parts that are no longer available and must be newly manufactured. Additional funding has been requested for fiscal years 2005 and 2006 to pay for the nonrecurring engineering required to manufacture these parts for the additional Block IIF satellites.

The GPS Operational Control System consists of monitor stations that passively track the navigation signals of all the satellites and a master control station that updates the satellites' navigation messages. Certain components of the control system have been delayed because funds from this development were reallocated to complete the

Block IIF development in support of constellation sustainment. Specifically, M-Code and Flex Power capabilities, part of the control system, will be delayed 3 years, but according to the program office, this will not result in underutilization of the satellites on orbit.

### Agency Comments

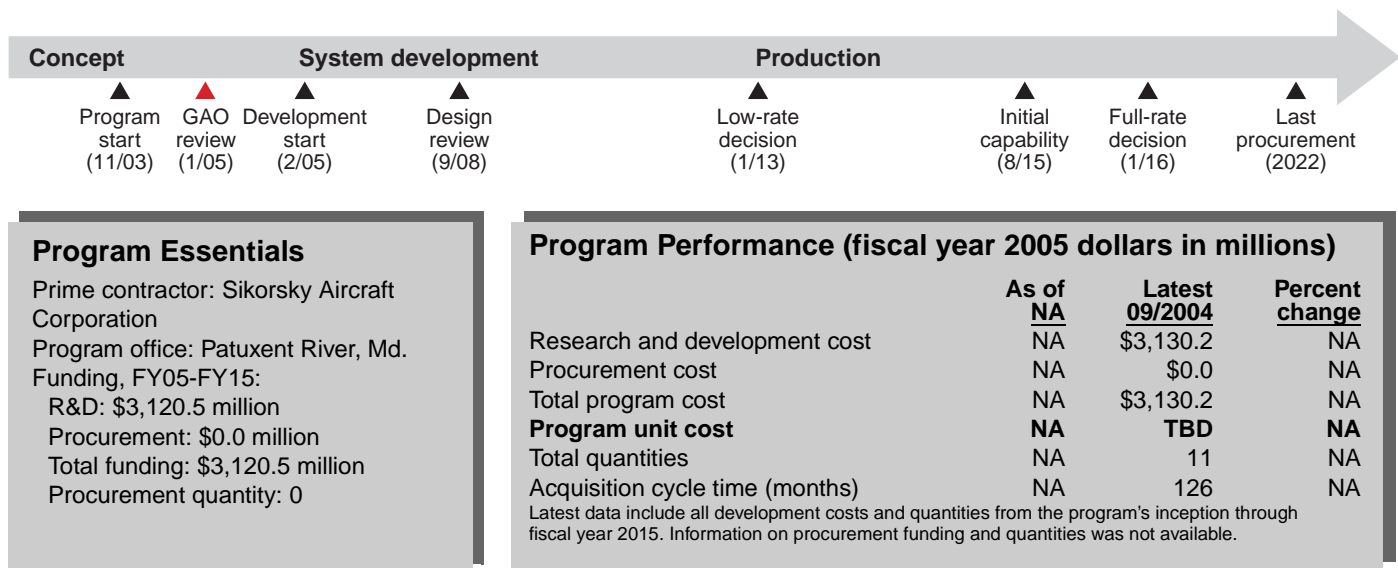
In commenting on a draft of this assessment, the Air Force stated that the GPS constellation first achieved final operational capability of 24 healthy and operational satellites in July 1995 and since then has consistently exceeded this requirement. It also stated that beginning in 2000, the joint program office initiated a modernization and upgrade program to more rapidly introduce new capabilities for the warfighter and civil users. It further stated that, as of December 2004, the joint program office's current estimate for launch availability of the first modernized satellite (IIR-M) will be April 2005 and that the Block IIF will continue the modernization program with its first satellite launch availability in September 2006.

## Heavy Lift Replacement (HLR)

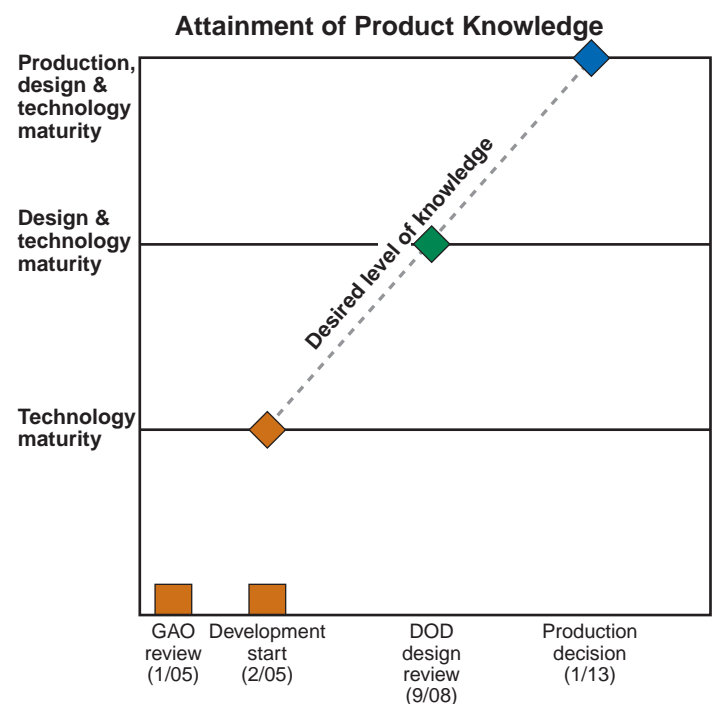
The Marine Corps' HLR system will perform the marine expeditionary heavy-lift assault transport of armored vehicles, equipment, and personnel to support distributed operations deep inland from a sea-based center of operations. The HLR program is expected to replace the current CH-53 helicopter with a new design to improve range and payload, survivability, reliability and maintainability, coordination with other assets, and overall cost of ownership.



Source: PMA-261 Program Office.



The critical technologies for the HLR program are not expected to be fully mature before the start of development in February 2005. An initial readiness assessment for the program identified 10 critical technologies. A subsequent assessment reduced that number to 3—the main rotor blades, the main rotor viscoelastic lag damper, and the main gearbox. Elements of the 7 eliminated technology areas, including the engines, may still present challenges to the program. The gearbox and the rotor blades are not expected to reach full maturity until 2011 and 2012, respectfully. Currently, an aggressive acquisition strategy is being planned.



## HLR Program

### Technology Maturity

The three critical technologies for the HLR program—the main rotor blades, the main rotor viscoelastic lag damper, and the main gearbox—are not expected to be fully mature before the start of development in February 2005. A lag damper similar to that planned for use is currently in operation on another program, but it must be resized for use on the HLR and therefore will not reach full maturity until the critical design review in 2008. The gearbox and the rotor blades represent new technology areas that have only been demonstrated in a low fidelity laboratory environment and are not expected to reach full maturity until 2011 and 2012, respectively.

Other development items may present future challenges to the HLR program. While 10 critical technologies were originally identified for the program, an assessment conducted in September 2004 reduced those to the 3 above. Of the 7 technologies eliminated, 2 are being developed by the HLR program and 5 are being developed by or used on other programs and will then have to be integrated onto the HLR platform. In either case, this integration can represent potential risks to cost and schedule. For example, the program is still considering five different engine design options. While the Navy has determined that none of the engine designs are expected to use new or novel technology or represent a new relevant environment for use, each requires different levels of design change, developmental risk, and qualification. For two other technologies, less desirable backup systems will have to be used if the technologies are not developed as planned.

### Other Program Issues

In September 2003, the Navy evaluated seven existing aircraft platforms and determined that only the CH-53E (with substantial enhancements) was capable of meeting requirements for performance, inventory, operational capability dates, operating and support costs, and survivability. Previous assessments concluded that the CH-53 airframe was experiencing substantial fatigue due to age and lack of regular upgrades and modifications. Program officials told us that this situation is even worse now due to increased operational use in Afghanistan and Iraq. The 2003 analysis evaluated four alternative CH-53E

designs and recommended one of these to meet range and payload requirements and minimize effects to service capability dates, inventory, support costs, and risk. However, after refining operational requirements for the HLR, the Navy selected a different alternative that offered additional performance and reliability improvements but added additional schedule and technical risk. To address these challenges, the Navy expects to implement an aggressive acquisition strategy for the HLR program, including sole-source contracting to Sikorsky Aircraft Corporation and a single-step acquisition approach. The program also intends to manufacture 50 of the 154 total helicopters (32 percent) during low-rate initial production and concurrent with initial operational testing. This concurrent production may help to field the systems sooner, but it could also result in greater retrofit costs if unexpected design changes are required.

### Agency Comments

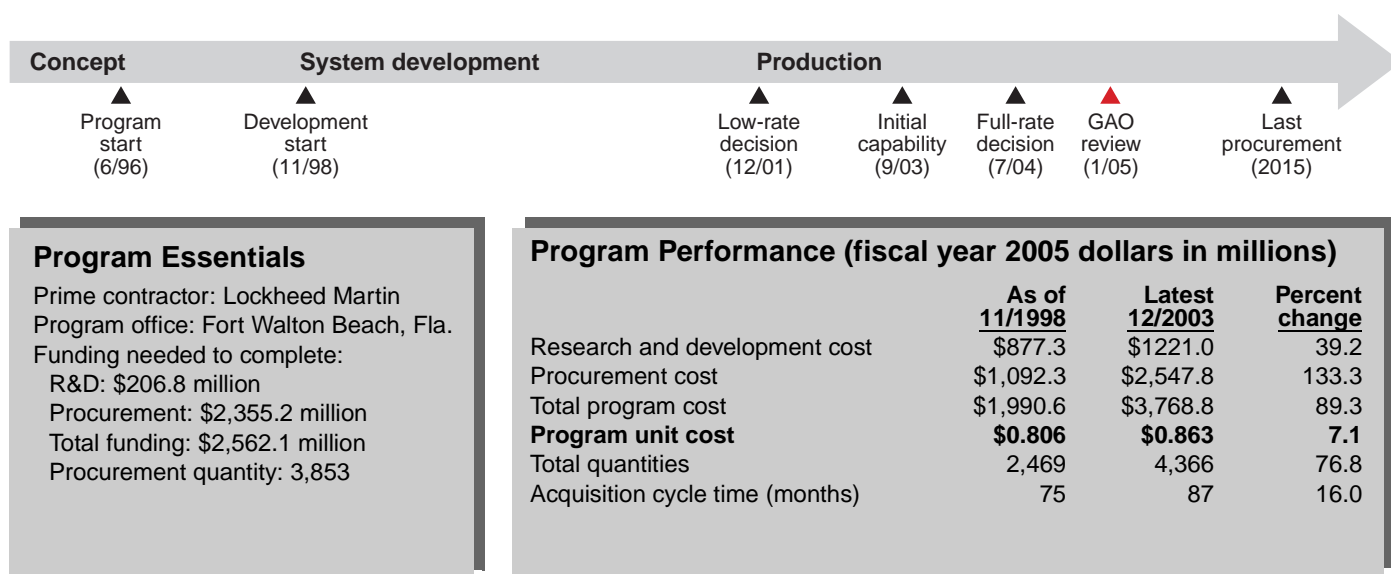
In commenting on a draft of this assessment, the Navy stated that the HLR program was developed to replace the aged CH-53E and support Marine Corps Sea Basing and other 21st Century joint operations. It added that the program balances operational and programmatic risks and that delays to the current HLR planned schedule will result in significant additional procurement and operation and support costs to support the CH-53E legacy aircraft and Marine Corps Heavy Lift shortfalls. The Navy noted that the Office of Naval Research endorsed the HLR program initiation at Milestone B and that the approved HLR Technology Readiness Assessment and maturation plan include the application of engineering trade and risk reduction prior to program initiation at Milestone B. It also noted critical technology item maturation events coincide with key system development events such as critical design review and prototype production. As the HLR program matures, risk reduction will continue to be abetted through sustained selection of nondevelopmental technologies, with an emphasis on employment of mature technologies common to Marine, Navy, and DOD weapon systems.

## Joint Air-to-Surface Standoff Missile (JASSM)

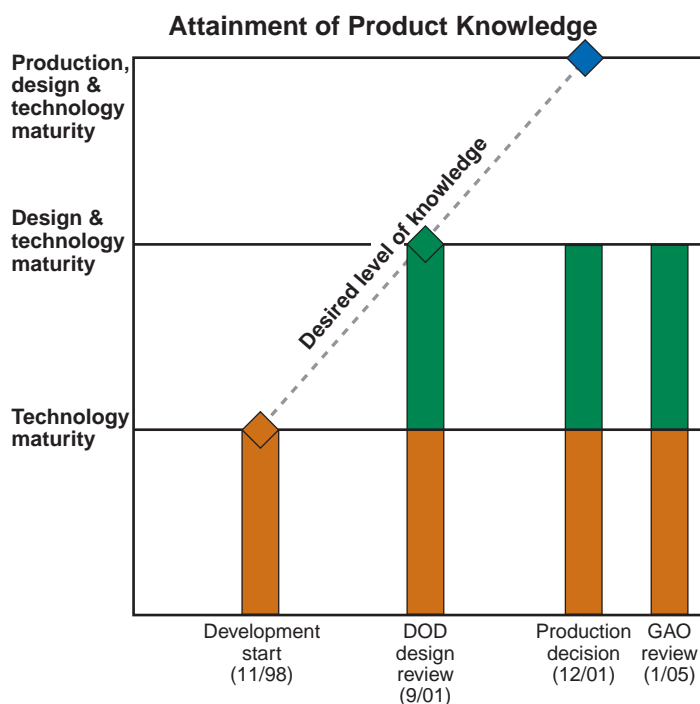
The JASSM is a joint Air Force and Navy missile system designed to provide a new capability to attack surface targets outside of the range of area defenses. The JASSM will be delivered by a variety of aircraft including the F-16 C/D, the B-52H, the F/A-18E/F, the B-2, and the B-1B. The system includes the missile, software, and software interfaces with the host aircraft and mission planning system. We assessed all components.



Source: Joint Air-to-Surface Standoff Missile (JASSM) Program Office (Development Test Mission - DT-5).



The JASSM program entered production in December 2001 without ensuring that production processes were in control. However, program officials indicated that they have demonstrated the production processes by sampling statistical data at the subsystem level and that four missiles are selected from each production lot and tested for quality. The JASSM program used mature technology, and the missile design was stable at the design review. Although there were some test failures in the developmental and operational tests run from April 2002 to September 2003, program officials incorporated fixes that subsequent tests demonstrated to be successful. However, in recent follow-on tests, the program continued to have test failures, and the Air Force suspended testing until the causes of these failures can be determined. Nevertheless, the JASSM was approved for full-rate production in July 2004.



## **JASSM Program**

### **Technology Maturity**

The JASSM program identified three critical technologies—global positioning system antispooing receiver module, low observable technology, and composite materials—and stated that all three are mature. They are new applications of existing technologies.

### **Design Stability**

The contractor has released 100 percent of the drawings to manufacturing. The program office completed developmental and operational tests and entered follow-on test and evaluation. Fourteen developmental flight tests were performed, with three tests failing to meet the test objectives. Program officials identified the issues involved and incorporated fixes, which were successfully tested in later developmental tests. Fifteen operational tests were conducted from June 2002 to September 2003. According to the Air Force Operational Test and Evaluation Command, 7 of these were successful, 5 were failures, and 3 were “no test.” Based on the developmental and operational tests, the Command considered the JASSM to be capable against the required targets but not reliable. Therefore, it rated the missile as effective and potentially suitable and recommended approval of full-rate production. Since that time, in follow-on test and evaluation, the missile had three successful tests and three failures. The Air Force halted further testing and convened a failure review board to determine the causes for the test problems. This board was to report its findings in October 2004.

### **Production Maturity**

Program officials do not collect production process control data at the system level. However, they stated that all production processes had been demonstrated and that statistical data are collected at the subsystem level and are sampled as required. Program officials indicated that the contractor has produced at the rates required for the low-rate initial production buy of 176 missiles and that it will be able to produce at the full-rate production level of 250 missiles per year. Three production lots are on contract and deliveries are on schedule. Program officials believe that none of the manufacturing processes that affect critical system characteristics are a problem, although there are key production processes that have cost implications, such as

bonding for the low observable materials and the painting/coating application. The missile was approved for full-rate production in July 2004.

### **Other Program Issues**

A contract for development of an extended range version of the missile was awarded in February 2004.

### **Agency Comments**

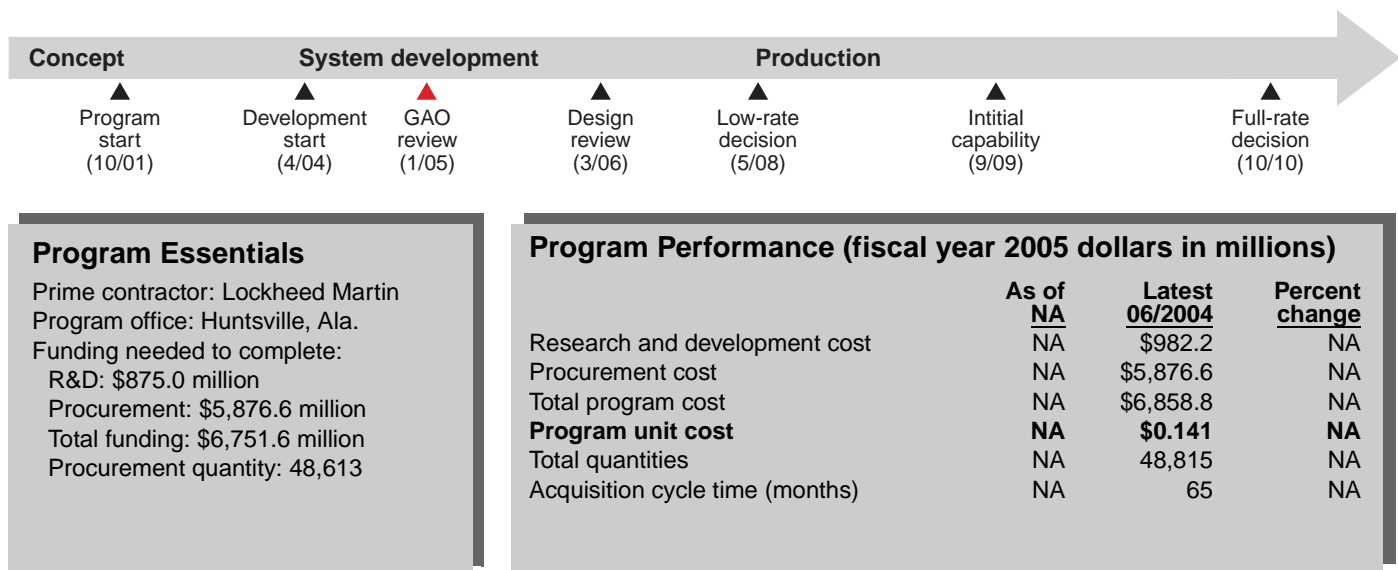
In commenting on a draft of this assessment, the Air Force stated that as a result of two test failures this summer, the Air Force Program Executive Office for Weapons convened a Reliability Enhancement Team on August 16, 2004, to investigate ways to improve reliability of the JASSM. It further stated that the team completed its work in October and concluded the JASSM design was sound, concurred with the joint program office return to test plan, and recommended award of the next lot's production contract—awarded November 2004. Also, the team recommended the Joint Program Office/Lockheed Martin pursue a more focused effort on subtier supplier manufacturing process quality controls and implement a robust test program to improve missile reliability. The Air Force stated that the key stakeholders (Air Force, Office of the Secretary of Defense, and Congress) concurred with the team's recommendations and the joint program office's way ahead plan and noted that the JASSM team continues to address near-term reliability issues identified by the Reliability Enhancement Team.

## Joint Common Missile (JCM)

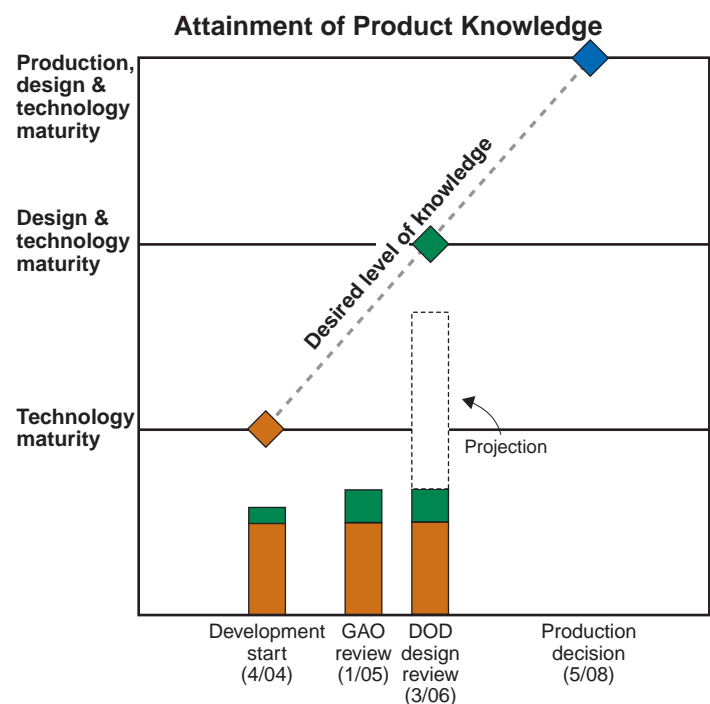
The Joint Common Missile is a joint Army/Navy program with Marine Corps participation and United Kingdom involvement. It is an air-launched and potentially ground-launched missile designed to target tanks; light armored vehicles; missile launchers; command, control, and communications vehicles; bunkers; and buildings. It is to provide line-of-sight and beyond line-of-sight capabilities and can be employed in a fire-and-forget mode or a precision attack mode. The missile will replace systems such as Hellfire and Maverick.



Source: Joint Common Missiles Program Office.



The Joint Common Missile entered system development of the air-launched version in April 2004, before any of its critical technologies were fully mature. At this time, program officials do not know the number of drawings that will be released by design review in March 2006. Program officials currently project that the critical technologies will reach maturity 3 months prior to design review, about half way through product development. Until all technologies are demonstrated, the potential for design change remains. Mature backup technologies are available should the new technologies fail to mature; however, use of backup technologies could degrade system performance or increase costs. By beginning integration before these technologies have been demonstrated, the potential for cost growth, schedule delay, or decreased performance exists.



## **Joint Common Missile Program**

### **Technology Maturity**

None of the Joint Common Missile's three critical technologies have demonstrated full maturity according to best practices. These technologies include a multimode seeker for increased countermeasure resistance, boost-sustain propulsion for increased standoff range, and a multipurpose warhead for increased lethality. Program officials noted that many of the components of these technologies are currently in production on other missile systems, but they have not been fully integrated into a single missile. Maturing technologies concurrently with product development increases the potential for cost growth and schedule delays. According to program officials, while backup technologies exist for each of the critical technologies, substituting any of them would result in degraded performance or increased costs.

### **Design Stability**

Currently, about 16 percent of the drawings for the Joint Common Missile have been released to manufacturing. Program officials project that approximately 41 percent of the drawings will be released by May 2005, the end of what they term a risk mitigation phase. However, program officials have not projected the number of drawings that will be released by design review in March 2006. Officials project full integration of the subsystems into the Joint Common Missile will occur by April 2005, although the system will reach technology maturity by December 2005, over a year and a half after the start of system development.

Program officials stated that the program's modular design will reduce life-cycle costs, including demilitarization, and will enable continuous technology insertion to provide improved capability against advancing threats.

### **Agency Comments**

In commenting on a draft of this assessment, the program office stated that during the first and second quarters of fiscal year 2004, a comprehensive Technology Maturity and Readiness Assessment, along with a risk assessment, was performed by subject matter experts from the Aviation and Missile Research and Engineering Center and the Army Test and Evaluation Command and coordinated with respective offices within the Army and the Navy.

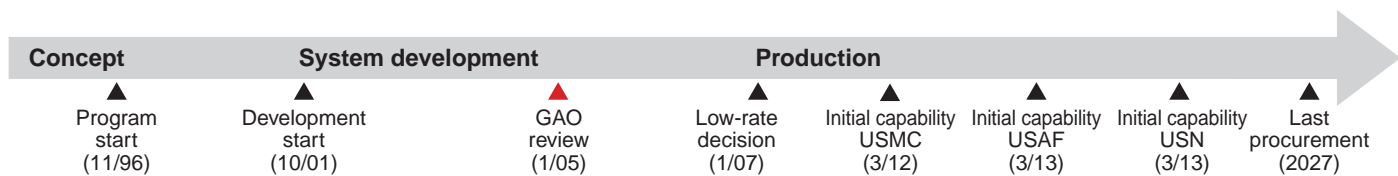
This assessment was reviewed by the Department of the Army, the Office of the Secretary of Defense, and the Director of Defense Research and Engineering and concluded that the Joint Common Missile technology was at an appropriate maturity level to support entry into System Design and Development. Further, it is anticipated that progress will continue. The system technologies combined with control test vehicle firing(s) will substantiate maturity according to best practices by April 2005.

## Joint Strike Fighter (JSF)

The JSF program goals are to develop and field a family of stealthy, strike fighter aircraft for the Navy, Air Force, Marine Corps, and U.S. allies, with maximum commonality to minimize costs. The carrier suitable version will complement the Navy's F/A-18 E/F. The conventional take-off and landing version will primarily be an air-to-ground replacement for the Air Force's F-16 and A-10 aircraft, and will complement the F/A-22. The short take-off and vertical landing version will replace the Marine Corps' F/A-18 and AV-8B aircraft.



Source: JSF Program Office.



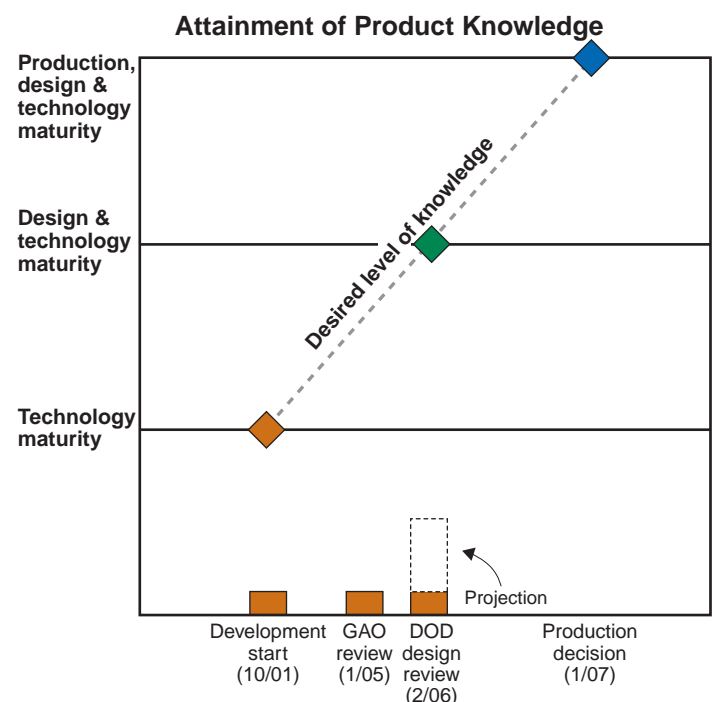
### Program Essentials

Prime contractor: Lockheed Martin  
 Program office: Arlington, Va.  
 Funding needed to complete:  
 R&D: \$28,664.3 million  
 Procurement: \$154,854.5 million  
 Total funding: \$183,678.6 million  
 Procurement quantity: 2,443

### Program Performance (fiscal year 2005 dollars in millions)

	As of 10/2001	Latest 12/2003	Percent change
Research and development cost	\$33,478.4	\$43,566.3	30.1
Procurement cost	\$148,528.2	\$154,854.5	4.3
Total program cost	\$183,561.2	\$198,624.5	8.2
<b>Program unit cost</b>	<b>\$64.048</b>	<b>\$80.840</b>	<b>26.2</b>
Total quantities	2,866	2,457	-14.3
Acquisition cycle time (months)	185	196	5.9

The JSF entered system development in 2001 with its critical technologies immature, and recent assessments indicate that this is still the case. Other risks exist as well. For example, the preliminary design review revealed a significant weight problem that led to numerous design and requirement changes. This resulted in delays of 16-22 months for the design reviews and increased costs. The program expects 35 percent of its drawing packages to be completed by the design reviews. Also, the program expects to produce a significant number of production aircraft with little demonstrated knowledge about performance, reliability, software maturity, and producibility. In 2004, the program reported a Nunn-McCurdy (10 U.S.C. 2433) unit cost breach largely due to design maturation efforts, schedule extensions, and revised labor and overhead rates.



## JSF Program

### Technology Maturity

The JSF entered system development without demonstrating the maturity of its 8 critical technologies. Data provided by the program office indicate that the technology maturity has not significantly changed. In 2004, an independent review team examined the program and identified several technical challenges related to the critical technologies. For example, it found that the highly integrated subsystems still have risk and that major challenges remain with the mission systems and software integration. The team reported that prognostics and health management technologies needed a focused initiative to mature them.

### Design Stability

When development began, the design was not well defined, leading to changes in requirements and design. The preliminary design review held in March 2003 revealed significant airframe weight problems—eventually exceeding targets by as much as 25 percent—that affected the aircraft's ability to meet key performance requirements. Actions to resolve the problem have added 18 months and \$4.9 billion to the development program.

Program officials indicated that no drawings have been completed for any production representative variant. Critical design reviews are scheduled for the 2006 time frame, a 16- to 22-month delay. At the time of the design reviews, the program expects to have released about 85 percent of the critical structural drawings but only 35 percent of the total engineering drawing packages needed to build the aircraft. This relatively low level of design knowledge will continue beyond the production decision in 2007. At the time of that commitment, the JSF will (1) have done limited flight testing on only one nonproduction representative aircraft; (2) not have flight-tested an integrated aircraft (with critical mission systems and prognostics technologies); (3) have less than 40 percent of the software lines of code needed for expected system functionality released. By 2013, when development is scheduled to be complete, DOD plans to have bought around 500 low-rate production aircraft at an estimated cost over \$50 billion. This highly concurrent strategy of producing and developing aircraft increases the risks of cost growth and delays in delivering capability to the warfighter.

### Production Maturity

The program office is collecting information on the JSF production processes. The contractor is currently in the process of identifying the key characteristics, critical manufacturing processes and capturing some early data. At the time of the production decision, the program will not have demonstrated that the aircraft can be produced efficiently or with expected reliability. These uncertainties are major contributors for DOD plans to rely on cost reimbursable type contracts for the early production buys. Fixed price contracts, the norm for production, are not expected until the air vehicle has a mature design, has been demonstrated in flight tests, and is producible at established cost targets.

### Other Program Issues

In 2004, the program reported a Nunn-McCurdy (10 U.S.C. 2433) program unit cost breach. According to the program office, total program unit costs have increased by 19.4 percent largely due to aircraft design maturation efforts, schedule extensions, and revised labor and overhead rates.

### Agency Comments

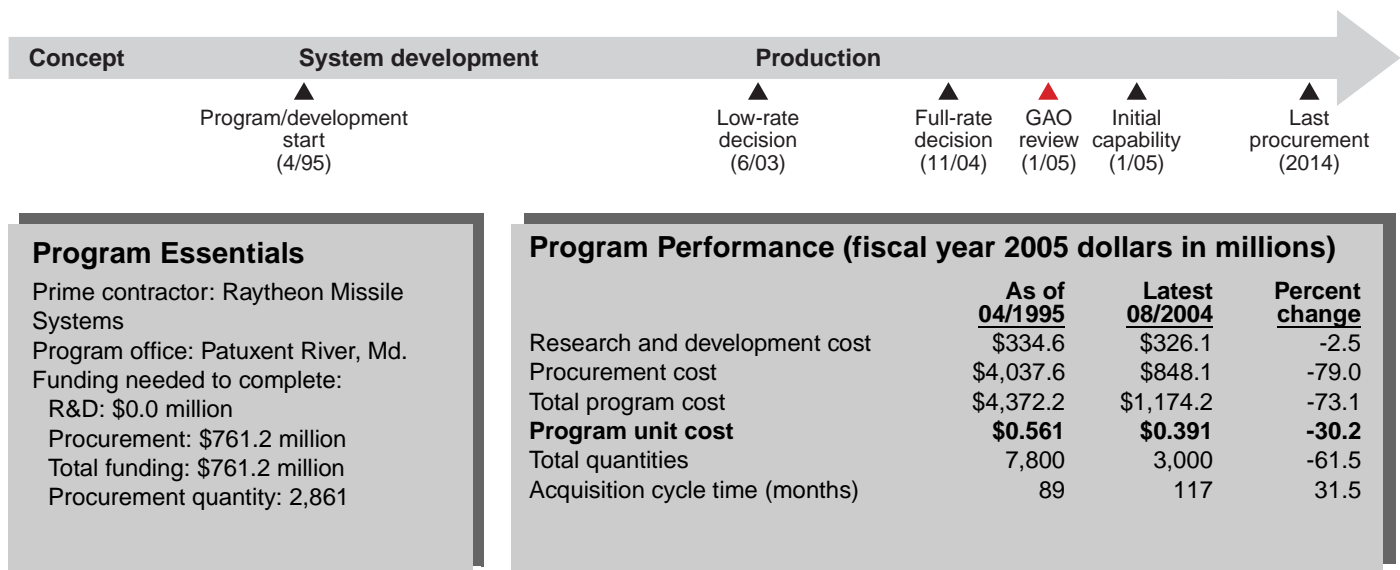
In commenting on a draft of this assessment, the Air Force provided the following information. A 2001 DOD review concluded the JSF had demonstrated sufficient technical maturity for entry into development. Design reviews were completed March 2004 on all areas except the airframe. By the airframe design review, 85 percent of the critical structural drawings will be complete. Subsystem hardware/software integration in the lab is ahead of schedule, occurring sooner than legacy fighter programs. Significant progress has been made in weight and performance issues. The short take-off and vertical landing variant includes over 2,700 pounds of weight reductions achieved through design optimization. More weight improvements were achieved by modest requirement changes endorsed by the warfighters. Requirements for other variants were not changed. Manufacture of the first test aircraft is underway, with assembly times less than planned. Over 1,500 test hours have been achieved on seven engines. Some replan refinements are in work. Program concurrency reflects spiral development strategy.

## Joint Standoff Weapon (JSOW)

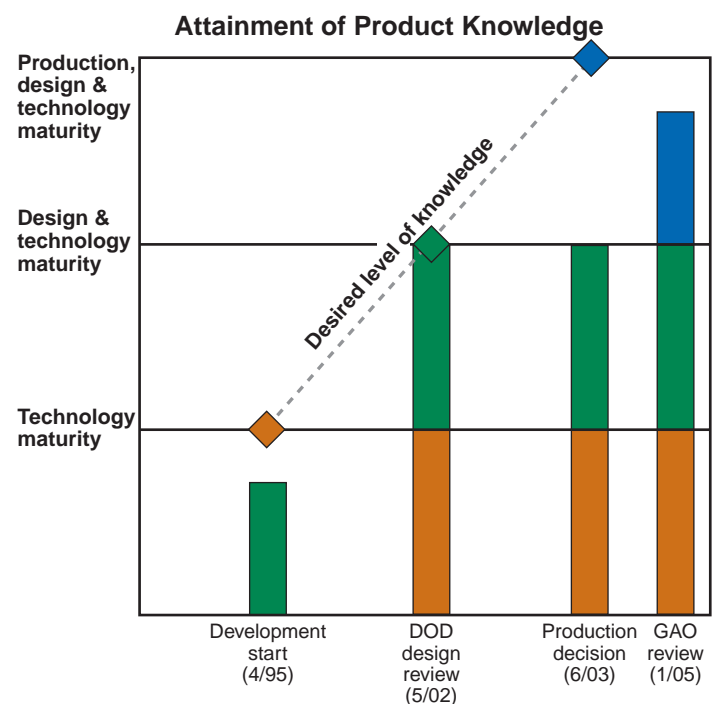
The JSOW is a joint Air Force and Navy guided bomb to attack targets from outside the range of most enemy air defenses. A dispenser variant (JSOW A) carries submunitions to attack soft targets. In 2002, the Joint Requirements Oversight Council deferred production of an antiarmor JSOW variant (JSOW B). The unitary variant (JSOW C) uses a seeker, autonomous targeting acquisition software, and a single warhead to attack targets. All the variants use a common air vehicle. We assessed the unitary variant and the common air vehicle.



Source: Raytheon Systems Company.



The JSOW program began low-rate production in June 2003 without knowing whether production processes were in control. However, the contractor has since identified seven critical production processes and has five of the seven under statistical process control and performing at an acceptable quality level. The contractor is working with the remaining two processes to collect enough data to verify that the processes are under control. Operational evaluation was completed in September 2004, and the beyond low-rate production and live fire test reports required to support the full-rate production decision were received in December 2004.



## **JSOW Unitary Program**

### **Technology Maturity**

The JSOW Unitary variant's technology is mature. The program office identified the imaging infrared seeker with the autonomous acquisition software as the only critical technology for the system. The seeker was not mature at the start of development, but it did demonstrate maturity in October 2001—about three-fourths through development—when it was flown aboard an aircraft in a captive flight test. Program officials stated that in seven developmental tests, three free-flight tests with the seeker only and four combined seeker/warhead tests, the seeker's performance substantially exceeded requirements. The seeker has demonstrated greater accuracy than required during operational testing.

### **Design Stability**

The JSOW unitary variant's basic design is complete. At the system design review in May 2002, the program office had completed 99 percent of the drawings. The Navy has completed 10 developmental tests (adding one combined seeker/warhead test in 2003) in its development program—3 sled tests with the warhead, 3 free-flights with the seeker, and 4 combined warhead/seeker tests. After some delay in beginning operational tests due to problems with the fuze, the Navy completed operational testing in September 2004 and reported that the fuze reliability met requirements.

### **Production Maturity**

Raytheon and the Navy identified seven critical processes unique to seeker development and collected data during low-rate production to determine that five of the seven were in control. Raytheon is working to collect data sufficient to characterize the remaining two processes. The Navy reports that delivery of the seekers is ahead of schedule and that there is low risk to meeting the quantity requirements of 17 per month. Raytheon has maintained its on-time deliveries for the common air vehicle for more than 33 months.

### **Other Program Issues**

The JSOW completed operational testing in September 2004. Preliminary analysis of the data indicated that the missile, its seeker, and warhead met performance requirements. The final report

rated the weapon as operationally effective but noted some deficiencies in training affecting the rating for suitability. According to a program office official, the issues have been resolved and the revised assessment rates the weapon as operationally effective and suitable. Reports detailing the analysis of the testing and the weapon's operational suitability and effectiveness and its live fire test results were received in December 2004.

### **Agency Comments**

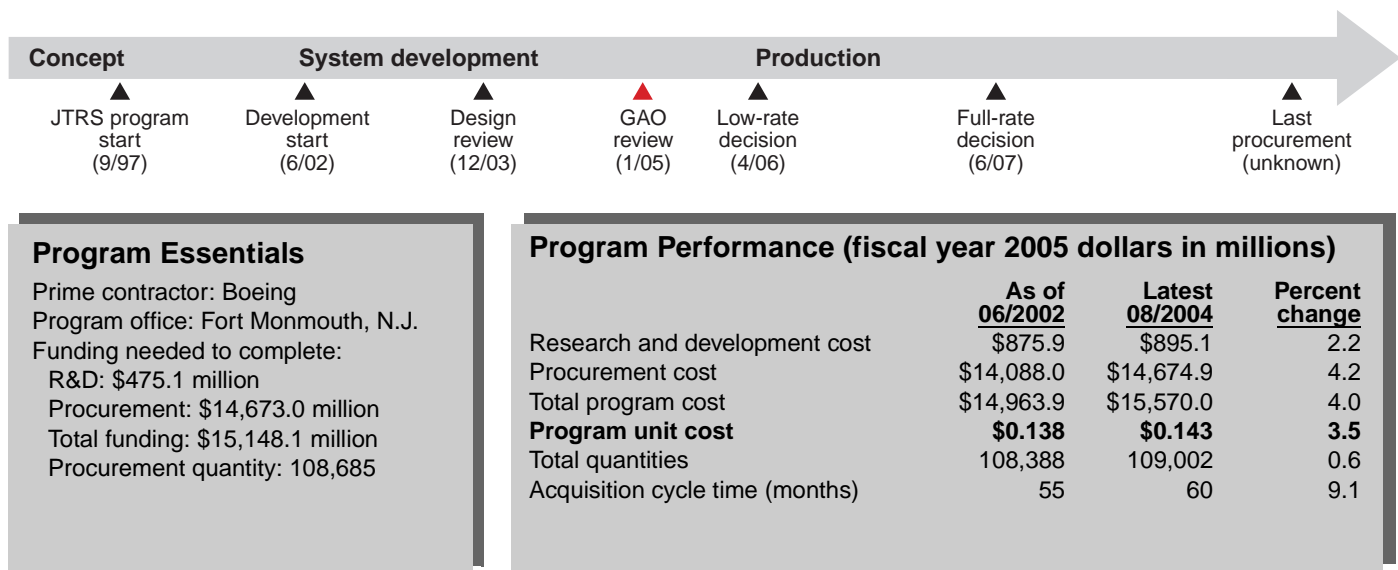
The Navy provided technical comments to a draft of this assessment, which were incorporated where appropriate.

## Joint Tactical Radio System (JTRS) Cluster 1

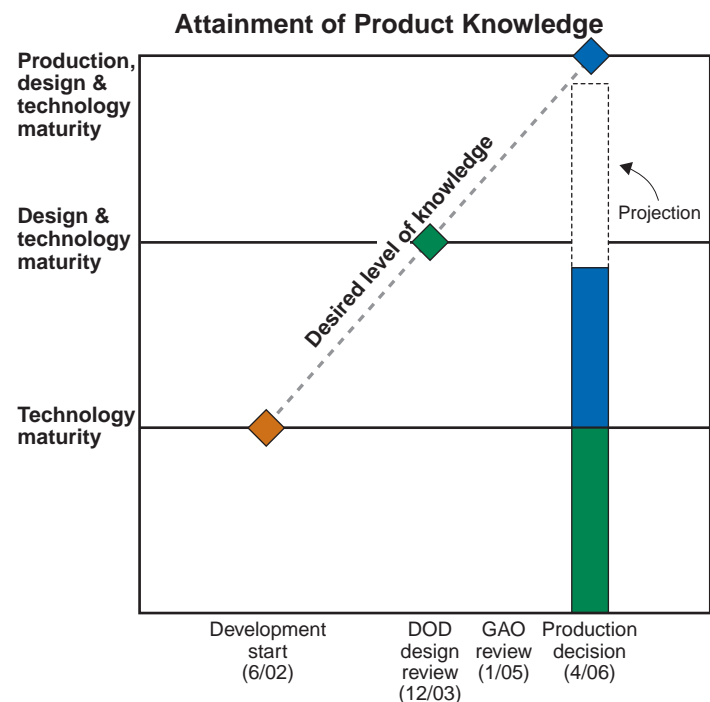
The JTRS program is developing software-defined radios that will interoperate with existing radios and significantly increase communications capabilities. A joint service program office is responsible for developing the JTRS architecture and waveforms, while service-led program offices will develop and procure radio hardware for platforms with similar requirements. This is an assessment of Cluster 1, led by the Army, which is developing radios for ground vehicles and helicopters.



Source: PM WIN-T JTRS Cluster 1.



The JTRS program's demonstrated knowledge continues to be difficult to characterize. Program officials believe that the design is stable and production processes are in control. However, design and production knowledge are dependent on technology maturity. None of the program's 20 critical technologies are mature, and the number of drawings has nearly tripled since last year. The program is proceeding under an accelerated strategy that does not allow for testing the radio's full functionality before initial low-rate production begins. Requirements changes are being considered that could result in design changes. The Army is proposing to restructure the program, which may add time to the development schedule.



## JTRS Cluster 1 Program

### Technology Maturity

While the program office has made some progress in maturing critical technologies, none of the JTRS Cluster 1 program's 20 critical technologies are mature. Many of these critical technologies have been used in other radio applications but cannot be assessed as mature because they have not been integrated into a complex radio like Cluster 1. Mature backup technologies exist for some critical technologies, but program officials have cautioned that substituting them would complicate integration or result in degraded performance. Program officials pointed out several challenges in achieving technological maturity. In particular, the program continues to reconcile size, weight, and power requirements. Meeting the performance objectives of the Wideband Networking Waveform is also a challenge. Program officials expect to demonstrate maturity of all 20 critical technologies during an early operational assessment scheduled to end in April 2005.

### Design Stability

The program reports achieving design stability for the basic Cluster 1 radio design. However, while all drawings have been released to manufacturing, the total number of drawings has nearly tripled from last year's assessment. Program officials primarily attribute the large increase to additional drawings required for certain components as the design matured and more specificity of the initial component drawings. Furthermore, program officials report that the number of drawings is likely to change again as a result of the upcoming operational assessment and as they move toward production. Given that the critical technologies have yet to mature, the significant changes to the number of drawings raise concerns about the program's design stability.

### Production Maturity

The program reports that all production processes to be utilized in manufacturing the JTRS radios are mature and in control. However, as the program office expected, the number of processes has decreased from last year's assessment. According to the program office, the number has decreased because of design enhancements. The program office expects the number of processes to change again as further design requirements take place.

### Other Program Issues

The program has a software development plan with insufficient schedule reserve to incorporate knowledge gained from initial development increments. It also has a compressed test and evaluation phase that leaves little room for rework. For example, the production decision is scheduled to occur immediately upon completion of an early operational assessment limited to pre-engineering development models that are not fully functional. The program office also reported an increase in procurement costs of over \$600 million primarily due to an error in estimating manufacturing costs. The JTRS Cluster 1 information security certification approach is also unprecedented, and the radios must go through a certification process that is outside the program office's control. In addition, the joint program office is exploring additional requirements including the development of additional waveforms that operate at above 2GHz—that may be tasked to the JTRS Cluster 1 program and may also necessitate hardware modifications. Because of emerging requirements and other technical challenges, the Army is considering restructuring the program, which may add more time to the development schedule.

### Agency Comments

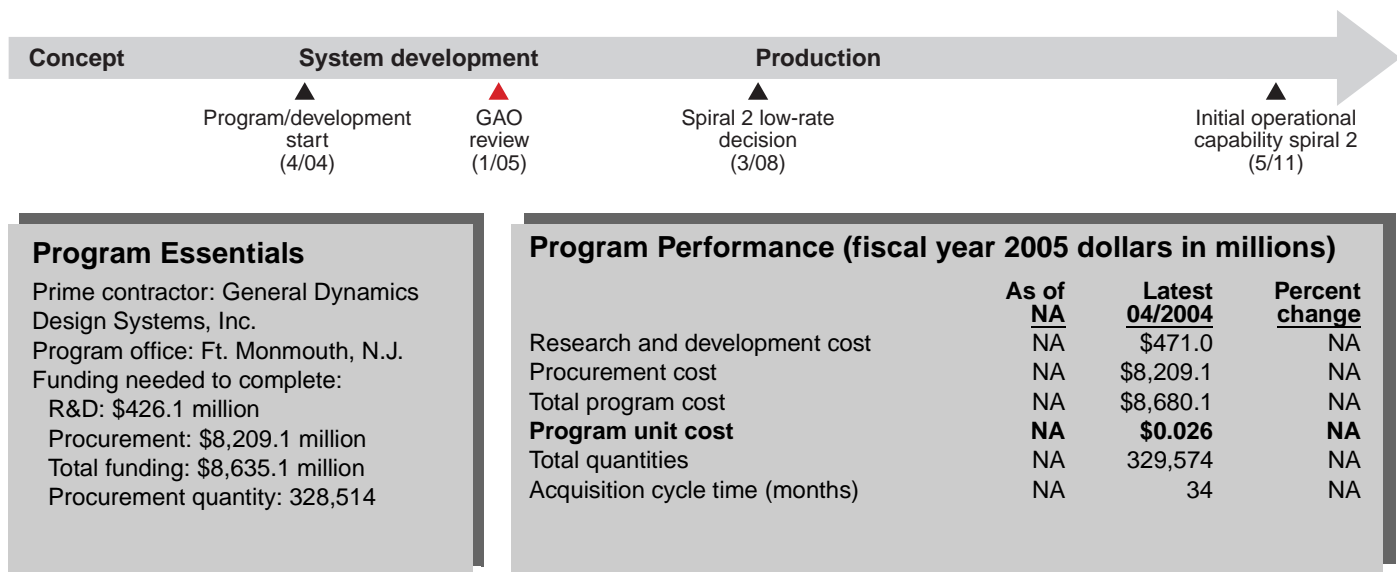
In commenting on a draft of this assessment, the program office generally agreed with the information provided in this report. Program officials also provided technical comments, which were incorporated where appropriate.

## Joint Tactical Radio System (JTRS) Cluster 5

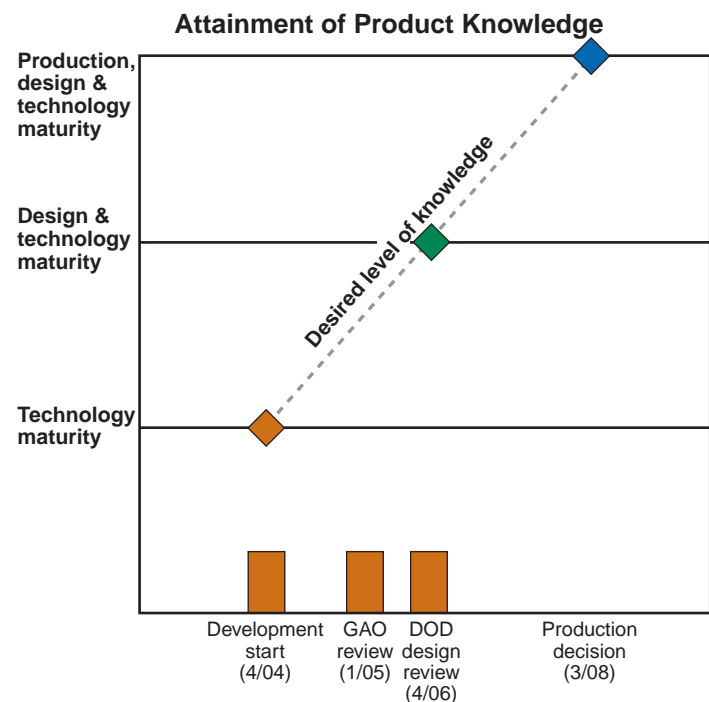
The JTRS program is developing software-defined radios that will interoperate with existing radios and also increase communications and networking capabilities. A joint service program office is developing the architecture and waveforms, while service-led program offices are developing radio hardware. The Army-led JTRS Cluster 5 is developing handheld, manpack, and small embedded radios for applications such as ground sensors. Spiral 1 will field a two-channel manpack. Spiral 2 will develop and field all versions. We assessed Spiral 2.



Source: PM WIN-T JTRS Cluster 5.



JTRS Cluster 5 began system development with one of its six critical technologies mature for Spiral 2. The program considers the five other technologies low risk and anticipates increased levels of maturity, though not full maturity, by the production decision in March 2008. We did not assess design stability because no production representative drawings had been released at the time of our assessment for either Spiral 1 or Spiral 2. The total number of drawings has also not been identified.



## **JTRS Cluster 5 Program**

### **Technology Maturity**

The JTRS Cluster 5 program has identified six critical technologies—identical for both of the Cluster 5 spirals. Spiral 1 is based on technologies that are either commercial-off-the-shelf or nondevelopmental items, and is focused on a two-channel manpack with narrowband capability operating seven of the designated JTRS waveforms. Spiral 2 is to evolve and expand Spiral 1 two-channel manpack capabilities as well as fully developing the one- and two-channel handheld and small form fit variants meeting the wideband and networking requirements.

The program office has assessed one of Cluster 5 critical technologies, termed environmental protection, as mature for use in Spiral 2. It has also assessed two other critical technologies, antenna and power management, at a high level of readiness, although not fully mature. However, the power management technology may not be as mature as assessed given the Cluster 5 requirement to support a JTRS Wideband Networking Waveform. This waveform is essential to providing JTRS networking services to ensure interoperability over a wide range of frequencies. While it is not designated a Cluster 5 critical technology, the JTRS Operational Requirements Document designates it as a key performance parameter. Operation of this waveform carries with it a large power requirement. Because of that power requirement and the technical challenges of meeting that requirement in an acceptable size and weight, the Cluster 5 program is seeking some relief from the waveform's requirements, and attempting to optimize the software code to increase its power efficiency. It is also evaluating alternative waveforms such as the Soldier Radio Waveform to provide in a power efficient way the needed networked services for radios with limited power and antenna size.

The remaining Cluster 5 critical technologies—antennas, microelectronics, multichannel architecture, and security—require additional development. According to the program office, however, all four represent a low level of risk and are anticipated to reach increased levels of maturity by the production decision.

Additionally, the program continues to address size, weight, and power requirements. The Cluster 5 manpack radios to be fielded in Spiral 2 are to have a maximum weight of 9 pounds. In comparison, Spiral 1 units weigh up to 13 pounds. With the help of the Army's Communications-Electronics Research, Development and Engineering Center, the program is pursuing power trade-offs and technical solutions to achieve the Spiral 2 requirement.

### **Design Stability**

We did not assess the design stability of JTRS Cluster 5 because the total number of drawings is not known and there are currently no releasable drawings complete for either spiral.

### **Other Program Issues**

An Acquisition Decision Memorandum in May 2004 authorized the movement of the single channel handheld radios requirement from Spiral 1 to Spiral 2. The memorandum also expressed concern about the immaturity of the Spiral 2 definition and required the program to update the cost and affordability assessment during the second quarter of fiscal year 2006. Furthermore, in recognition of the criticality of JTRS, it directed the Cluster 5 program to conduct a review in the first quarter of fiscal year 2005 to assess the maturity of the plans for Spiral 2. The JTRS Cluster 5 development contract was awarded in July 2004. However, immediately thereafter, the contractor was issued a stop-work order because of a bid protest. Work was stopped until late October 2004, when we denied the protest and work resumed. Impact of the stop-work order is still being assessed by the Cluster 5 product manager.

### **Agency Comments**

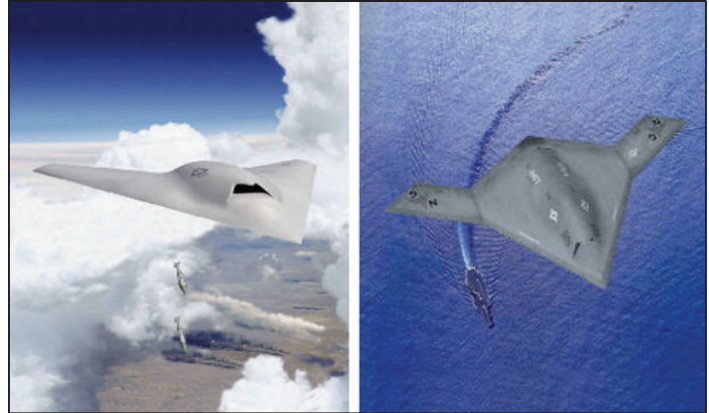
In commenting on a draft of this assessment, the program office provided some technical comments and suggested a number of editorial changes including additional clarifying information, which we incorporated as appropriate. The program office indicated the critical technologies will reach an acceptable level of maturity by the production decision in 2008.

### **GAO Comments**

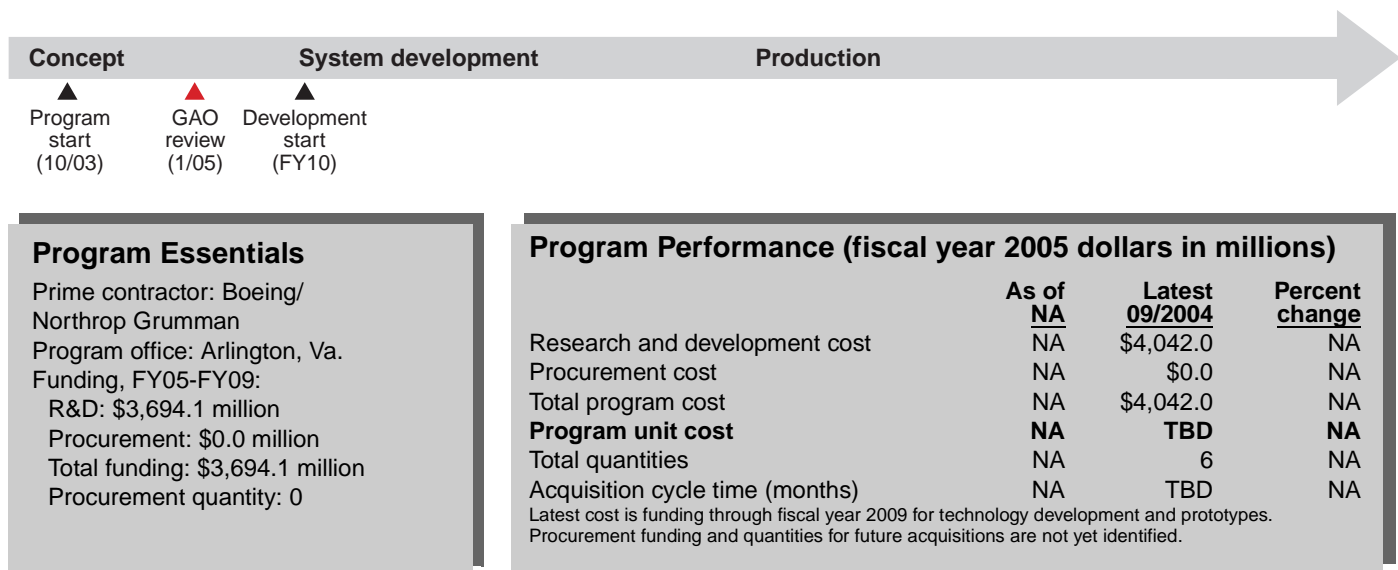
While the program office commented that the critical technologies will reach an acceptable level of maturity by the time of the production decision, best practices call for attaining a higher level of maturity by the start of development.

## Joint Unmanned Combat Air Systems (J-UCAS)

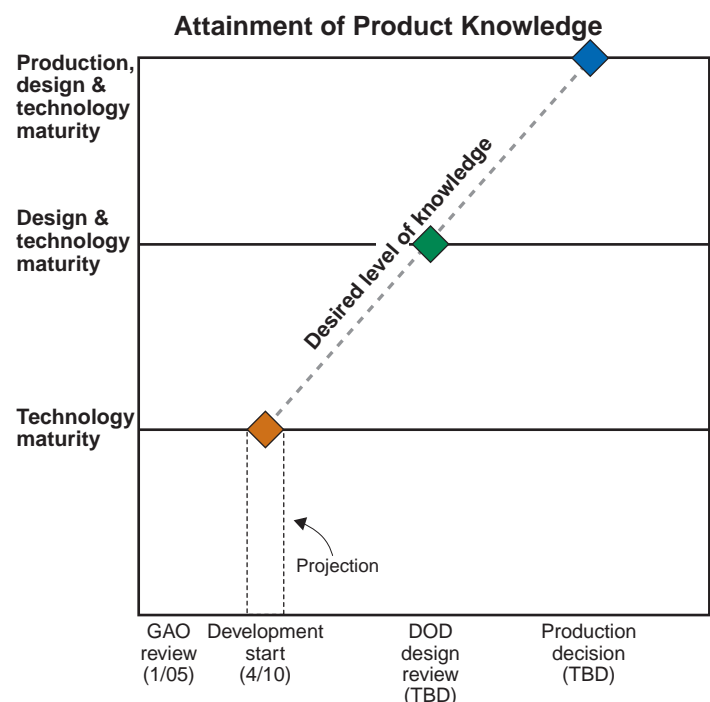
The J-UCAS program is a combined effort of the Defense Advanced Research Projects Agency (DARPA), the Air Force, and the Navy to demonstrate the technical feasibility and operational value of a networked system of high performance and weaponized unmanned air vehicles. Expected missions include the suppression of enemy air defenses, electronic attack, precision strike, and surveillance. The program consolidates two formerly separate service projects and is to develop larger, more capable, and interoperable aircraft.



Source: (left) X-45C - The Boeing Company, X-47B - Northrop Grumman Corporation, (right) X-45C © 2004 The Boeing Company, X-47B © 2004 Northrop Grumman Corporation.



The J-UCAS program began in October 2003 with technologies that officials project will sufficiently mature to support a possible 2010 start of operational system development. The program plans to develop and demonstrate the next generations of the original Air Force and Navy demonstrators that will have common performance objectives and utilize common subsystems and technologies. The program expects to conduct an early operational assessment starting in fiscal year 2007 and then provide the Air Force and the Navy with several program options for follow-on efforts. A December 2004 program budget decision would restructure the program and reduce funding. At the time of our review, it was not clear how these changes will impact the schedule for achieving key product knowledge.



## J-UCAS Program

### Technology Maturity

While none of the J-UCAS' six critical technologies are currently mature, program officials project that they will be sufficiently ready to support the early operational assessment scheduled to begin in fiscal year 2007 and to provide options to the Air Force and the Navy for follow-on efforts starting in fiscal year 2010. Program officials identified the following critical technologies needed to produce a high performance and networked system of low observable air vehicles capable of operating in high-threat environments for extended periods of time: (1) signature reduction; (2) advanced tactical targeting; (3) secure robust communications; (4) force integration, interoperability, and global information grid compatibility; (5) adaptive autonomous operations; and (6) operations in aircraft carrier-controlled airspace. These technologies are still maturing as would be expected at this early presystem development stage. The targeting and autonomous operations technologies are considered the most mature and carrier operations technology the least mature.

### Other Program Issues

The previous service-specific efforts combined in the joint program had different primary missions and operating environments. The Air Force began developing its system to suppress and attack enemy air defenses, while the Navy's primary interest was for a carrier-based unmanned aerial vehicle to provide persistent armed surveillance for the battle group. The joint program is expected to maintain a competitive environment and continue to develop next-generation versions of both Air Force and Navy demonstrators. Both versions will be expected to be capable of performing all required missions of the two services. By merging the Air Force and Navy efforts, DOD hopes for synergy and cost savings by developing interoperable and networked systems utilizing common operating systems, sensors, and weapons.

The program cost of over \$4 billion from startup in fiscal year 2004 through fiscal year 2009 does not include the approximately \$500 million spent on the two service-specific projects prior to consolidation. The program will compete for funding with current operational systems such as the Predator and the Global Hawk and other unmanned and manned

systems in varying stages of development, some with similar missions. Congress reduced J-UCAS funding in fiscal year 2005 because the program had not properly coordinated with the two services and directed that the technology demonstrators be completed in support of Air Force and Navy requirements.

A December 2004 program budget decision by DOD restructured J-UCAS by realigning adjusted resources to the Air Force to establish a joint program with Navy representation. It reduced total funding by about \$1.1 billion from fiscal year 2006 through fiscal year 2011.

Emerging challenges include adaptation for carrier operations and development of the common operating system. The projected weight for the new models increased from earlier estimates in order to meet range, payload, and persistence requirements. The common operating system is expected to integrate and provide for interoperability of J-UCAS air vehicles and is required to control groups of vehicles flying in a coordinated manner and functioning in the absence of human inputs. The program director said the common operating system is the most technically challenging aspect of the entire J-UCAS program.

### Agency Comments

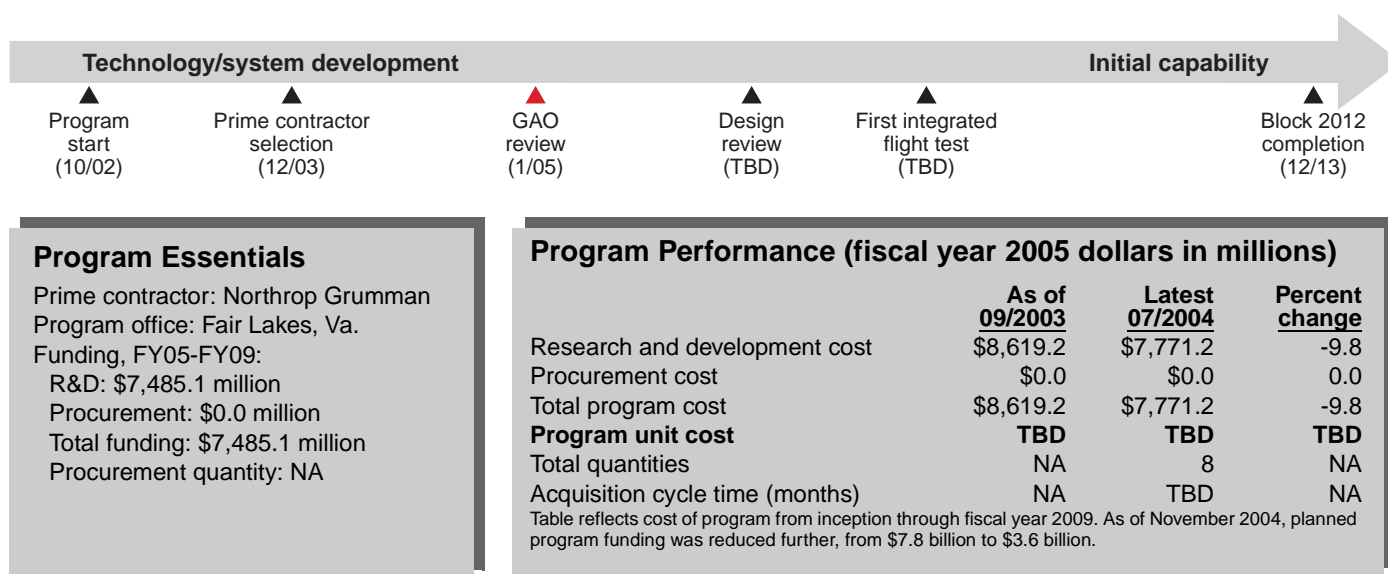
In commenting on a draft of this assessment, DARPA stated that the J-UCAS program, newly established when Congress considered fiscal year 2005 funding, is run under the guidance of a high-level executive committee and jointly manned with DARPA, Air Force, and Navy personnel. The Air Force and the Navy have fully coordinated on the demonstration approach using the X-45C and X-47B in support of service priorities. According to officials, the J-UCAS concept does not compete directly to replace any specific manned or unmanned system but will augment a transformed force structure and provide options to better address military needs in deep, denied adversary environments. DARPA also stated that in addition to the capabilities identified by the services today, J-UCAS will offer insights into new warfighting concepts. It will also preserve opportunities for competition in follow-on and derivative programs. Finally, DARPA noted that the common operating system, while technically challenging, encompasses essential mission functionality and offers the greatest potential return in flexibility and affordability.

## Kinetic Energy Interceptors (KEI)

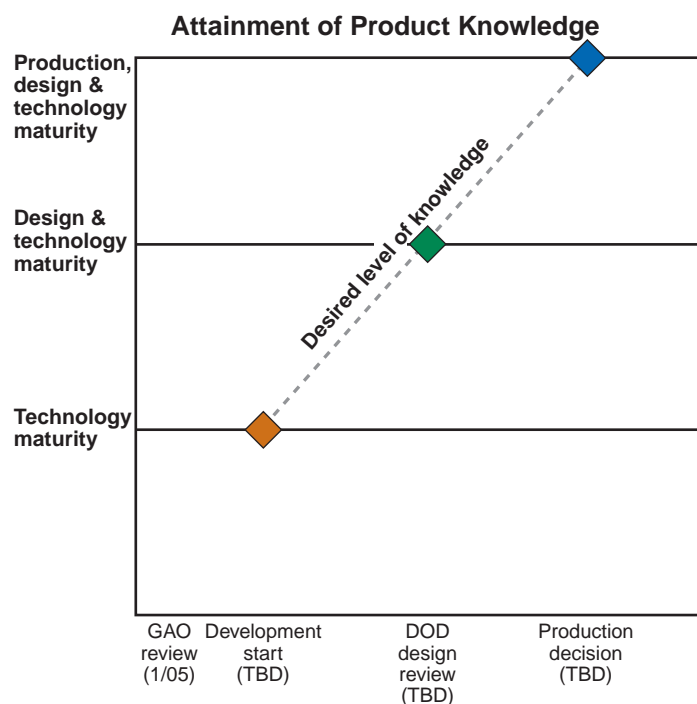
MDA's KEI element is a new missile defense system designed to destroy long-range ballistic missiles during the boost phase of flight, the period after launch during which the missile's rocket motors are thrusting. KEI would also engage missiles in the early ascent-phase, the period immediately after booster burnout. Key components include hit-to-kill interceptors, launchers, and battle management units. We assessed the proposed land-based KEI capability, which is planned to become available during 2012-2013 (Block 2012).



Source: Artwork developed jointly by KEI contractor and MDA.



All 7 KEI critical technologies are at a relatively low level of maturity, ranging from proofs of concept established through analytical or laboratory studies to new applications of existing technologies. For example, the program is leveraging existing interceptor technologies—infra-red seeker, third stage rocket motor, and divert system—that are currently used in other MDA programs. The program office rates the development of 2 critical technologies as high risk. The first involves one of the interceptor's booster motors, which demands high performance for KEI engagements. In addition, the program office judges the algorithm enabling the kill vehicle to identify the missile's body from the luminous exhaust plume as a high-risk technology. MDA expects to mature these technologies and integrate them into a land- and sea-based capability under the prime contract awarded in December 2003.



## **KEI Program**

### **Technology Maturity**

All 7 KEI critical technologies are at a relatively low level of maturity. These technologies are part of the element's interceptor, the weapon component of the element consisting of a kill vehicle mounted atop a boost vehicle. Of the 7 technologies, 4 pertain to the boost vehicle that propels the kill vehicle into space. They are its 2 types of booster motors, attitude control system, and thrust vector control system. The remaining 3 technologies pertain to the kill vehicle—its infrared seeker, divert system, and plume-to-hardbody algorithms. Although all technologies are immature, 3 of the 7 are derived from existing components in other missile defense programs. The infrared seeker and the third stage rocket motor come from the Aegis BMD program, and the divert system comes from the GMD program. Backup technologies exist for all but the infrared seeker, however, they are at the same low level of maturity as the critical technologies.

The program office noted that KEI critical technologies are not at a low level of maturity in and of themselves. The program's assessment—which rated each technology as relatively immature—was made from a systems perspective (i.e., it characterized the risk associated with integrating and demonstrating these technologies in the KEI environment). The 7 critical interceptor technologies will be assessed as mature if the program successfully completes its first intercept attempt of a boosting missile. This flight test is expected to be conducted sometime after 2010.

### **Design Stability**

At this time, the KEI program office does not have an estimate for the total number of drawings for any of its Block 2012 components (interceptor, launcher, and battle management unit). In addition to the number of drawings, the program plans to use other metrics to assess design maturity. Those metrics will include design, manufacturing, producibility, and quality measures for hardware and measures of maturity of the system's software.

### **Other Program Issues**

In fiscal year 2004, the KEI program underwent a program replan to compensate for anticipated fiscal year 2005 funding cuts and the addition of new requirements (e.g., nuclear hardening) imposed by

MDA. The original program called for a Block 2010 land-based capability to be available by the end of 2011. In the replan, the land-based capability was combined with the sea-based capability of Block 2012, both of which utilize the same interceptor. The KEI program is undergoing further restructuring. Based on comments received from the program office (see below), anticipated funding cuts beyond fiscal year 2005 are delaying the sea-based capability into Block 2014 (2014-2015 time frame) and deferring other activities indefinitely.

Because completion of the land-based capability continues to be pushed further in the future, the program's funding profile has changed. Under the plan to demonstrate an initial capability in the Block 2012 time frame, near-term funding through fiscal year 2009 was reduced by about 10 percent, with the balance shifted into later years. The latest restructuring noted by the program office further reduced funding by over 50 percent.

### **Agency Comments**

In commenting on a draft of this assessment, the program office provided information on the latest restructure of the KEI program. In short, program funding through fiscal year 2009 was reduced from \$7.8 billion (as listed) to \$3.6 billion and, accordingly, program activities such as development of the sea-based capability were delayed into future blocks.

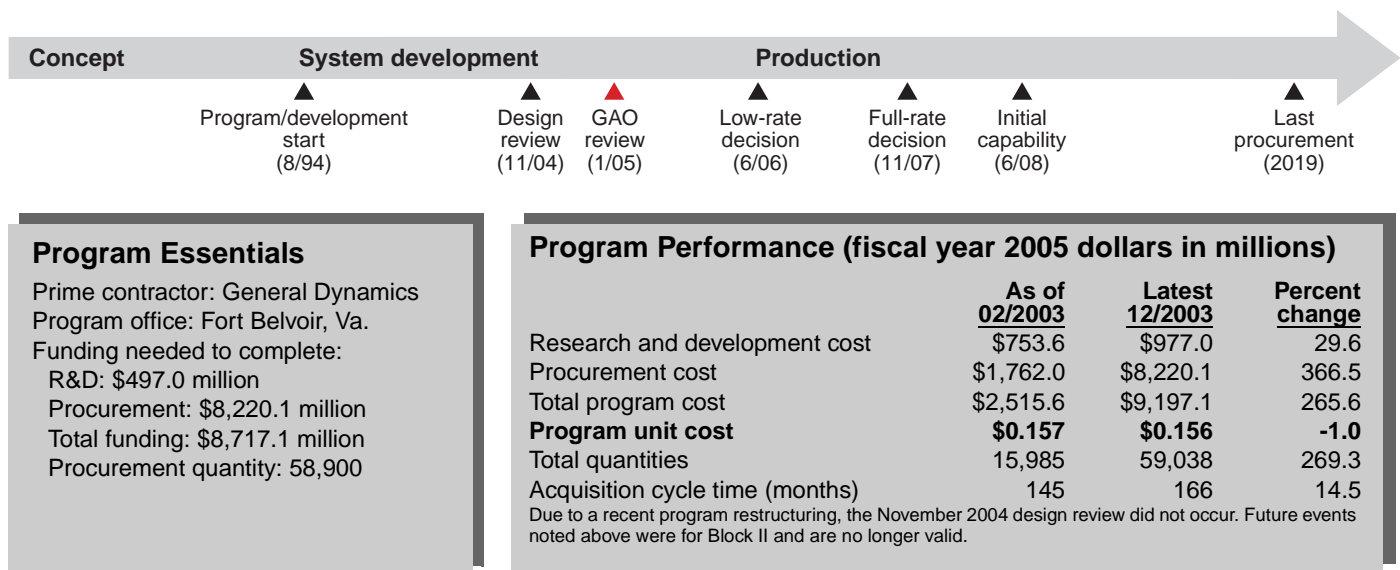
In addition, the program office indicated that "mission assurance" is the program's number one priority. In other words, the program's approach to element development is knowledge-driven, which places an emphasis on upfront systems engineering and analysis and other risk reduction activities.

## Land Warrior

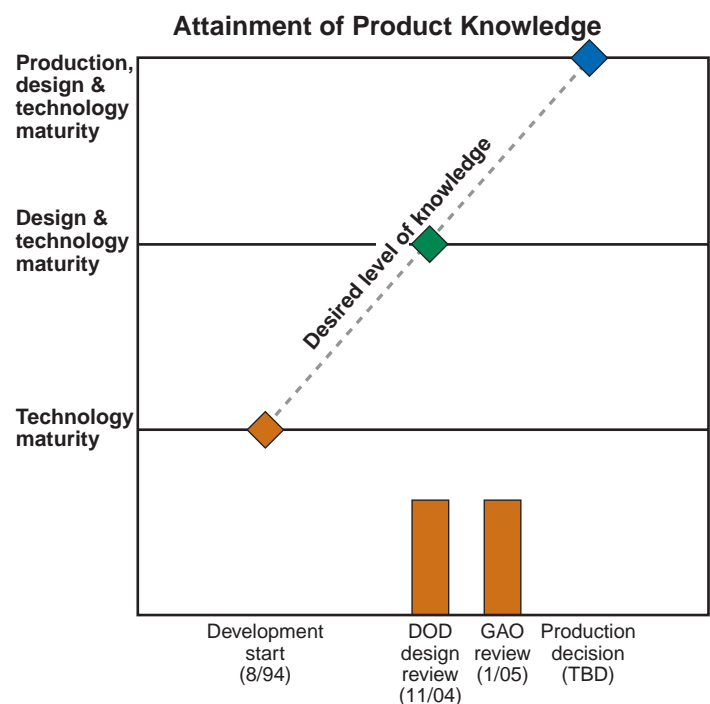
The Army's Land Warrior system is a modular, integrated, soldier-worn system of systems intended to enhance the lethality, situational awareness, and survivability of dismounted combat and support soldiers. Land Warrior comprises a computer-radio, integrated helmet assembly, weapon, software subsystem, and protective clothing. The Army terminated Block I (Land Warrior-Initial Capability) in 2003 due to low reliability in developmental testing and proceeded to Block II (Land Warrior- Stryker Interoperable). We assessed Block II.



Source: Program Executive Office Soldier.



Land Warrior entered system development in 1994 and today, two of the system's four critical technologies are mature. The program expects one of the remaining two—the personal area network—to be mature before the June 2006 low-rate production decision. The other technology—radio communications—is a risk area for the program because JTRS Cluster 5 embedded radios will not be available when needed. We could not assess the design stability of Land Warrior because the program was unable to supply complete design data. The program reported significant cost growth in 2003, due to an increase in the Army's planned procurement of Land Warrior systems and to increased Block II software and integration costs. The Army recently restructured the program, putting Block II on indefinite hold as the program focuses on fielding elements of the Land Warrior system to the current force.



## Land Warrior Program

### Technology Maturity

Two of the Land Warrior system's four critical technologies (the helmet-mounted display and power) are mature. Officials told us that despite concerns about the ability of industry to produce the helmet-mounted display in the quantities needed, the technology involved in the unit (which provides data and video) has been demonstrated and is mature. The commercial battery technology that will power Land Warrior is also mature, though overall power management remains a challenge due to irregularities in components' power consumption.

The other two critical technologies, the personal area network and radio communications, are not mature. The personal area network includes the connectors, cables, and interfaces that will link components of the soldier-worn ensemble to one another. Although such connections have in the past proven difficult, officials expect this technology to reach maturity before the June 2006 low-rate production decision. Land Warrior will eventually utilize the JTRS Cluster 5 embedded radio (assessed elsewhere in this report) when it becomes available in fiscal year 2011. Technology for this radio is not mature. In the interim, the Land Warrior program intends to use the Raytheon MicroLight Enhanced Position Location Reporting System (EPLRS), a single-channel, commercial-off-the-shelf radio. Program officials characterize the MicroLight as a cost-effective, short-term solution. Technology for the MicroLight could not be assessed as fully mature because it has not yet been integrated into the Land Warrior ensemble. Program officials said the MicroLight is smaller than other EPLRS radios in use today.

### Design Stability

We could not assess the design stability of the Land Warrior system because the program was unable to supply complete data on design drawings. The program cited changes resulting from an impending merger with the Army's Future Force Warrior technology integration effort as the complicating factor.

### Production Maturity

We could not assess the maturity of production processes for Land Warrior because the program is not collecting statistical process control data at this

time. Officials told us General Dynamics has not fully identified the key manufacturing processes, but that the company will measure production maturity in the future.

### Other Program Issues

The Land Warrior program has experienced significant challenges and delays in its 10-year history. The program restructured after contractor prototypes failed basic certification tests in 1998. Government testing in 2002 and 2003 revealed technical and reliability problems with Block I. The program manager terminated Block I shortly thereafter, and focused on developing Block II.

The Army recently restructured the program again, in response to congressional direction to immediately field some Land Warrior capabilities to the current force. The restructured program will produce capabilities in five spirals and has placed Block II on indefinite hold as it moves to field the Commander's Digital Assistant and the MicroLight EPLRS radio in "Spiral 0." The Army received a partial waiver in December 2004 to purchase a limited number of MicroLight radios, but radio communications will remain a risk area for the program until this issue is fully resolved. Officials said Spiral 0 is now the program's most pressing concern, and that the schedule for future spirals is being determined at this time. In addition, the program is planning to merge its efforts with the Army's Future Force Warrior technology integration effort, as directed in the Conference Report accompanying the Department of Defense Appropriations Act for Fiscal Year 2005. Congress also reduced the program's fiscal year 2005 budget by \$15 million due to anticipated efficiencies resulting from this merger.

The program reported significant cost growth in 2003, due mainly to an increase of more than 40,000 units in the Army's planned procurement of Block II Land Warrior systems to equip a broader range of soldiers than previously envisaged. Development costs also increased nearly 30 percent due to software development and vehicle integration requirements for Block II.

### Agency Comments

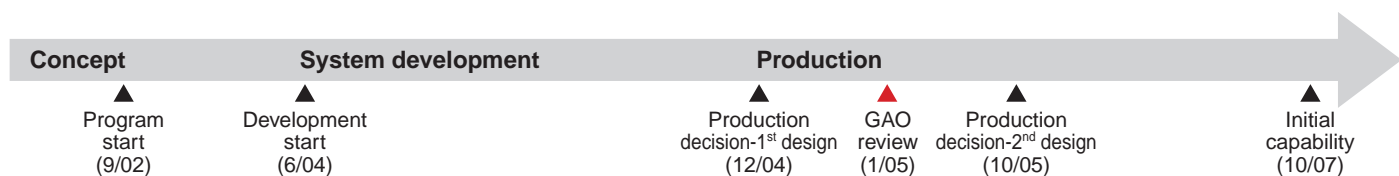
In commenting on a draft of this assessment, the Army generally concurred with our assessment and provided technical comments, which we incorporated as appropriate.

## Littoral Combat Ship (LCS)

The Navy's Littoral Combat Ship is to be a fast, maneuverable, shallow draft, surface combatant optimized for littoral warfare. LCS will employ innovative hull designs and reconfigurable mission packages to counter antiaccess threats in three mission areas: mine, antisubmarine, and surface warfare. This review focuses on the technology maturity of the mission packages associated with the acquisition of the first group of ships. Since competition for the remainder of the ships continues, we assessed only the mission modules.



Source: Littoral Combat Ship Program Office.



### Program Essentials

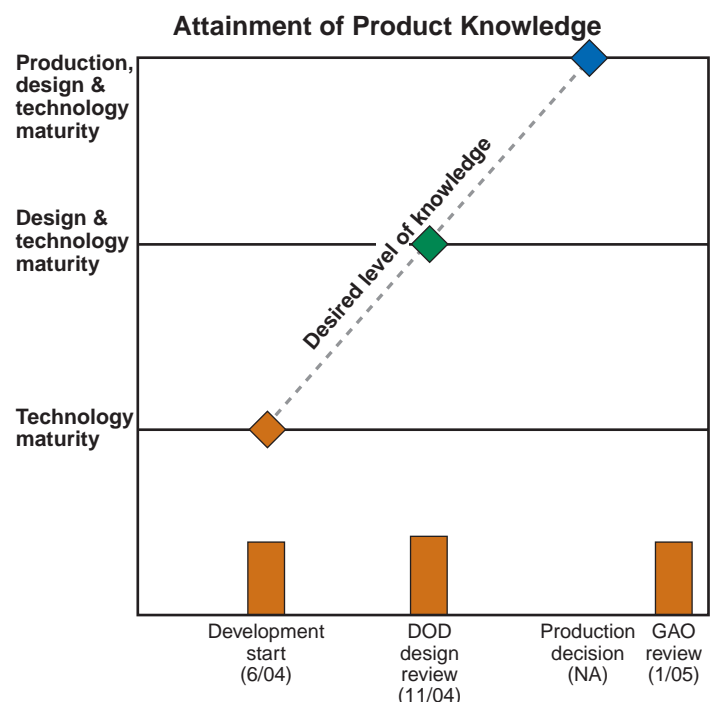
Prime contractor: General Dynamics, Lockheed Martin  
 Program office: Washington, D.C.  
 Funding needed to complete:  
 R&D: \$1,092.0 million  
 Procurement: \$810.1 million  
 Total funding: \$1,902.1 million  
 Procurement quantity: 4

### Program Performance (fiscal year 2005 dollars in millions)

	As of 05/2004	Latest 08/2004	Percent change
Research and development cost	\$1,187.9	\$1,227.4	3.3
Procurement cost	\$752.6	\$810.4	7.7
Total program cost	\$1,940.5	\$2,037.8	5.0
<b>Program unit cost</b>	<b>\$485.135</b>	<b>\$509.446</b>	<b>5.0</b>
Total quantities	4	4	0.0
Acquisition cycle time (months)	41	41	0.0

The first and third ships will be procured using research and development funds. Quantity shown is the number of ships procured, seven mission packages will also be procured with funds shown.

The program office identified 42 critical technologies. In June 2004, the LCS program entered system development with 14 of these 42 technologies mature. Five of the remaining 28 technologies are close to being mature. However, none of the 28 technologies were projected to demonstrate full maturity until after design review in November 2004. The acquisition schedule for LCS calls for deploying several critical technologies as prototypes or engineering development models for the first group of ships. The technologies that have not reached maturity affect all three of the littoral warfare missions: mine warfare, antisubmarine warfare, and surface warfare. The program office designated certain information competition sensitive. As a result, we have depicted only the level of knowledge for the LCS mission packages. The Navy has stated that the total program level of knowledge is higher.



## LCS Program

### Technology Maturity

Nine of the technologies under development for LCS are used in multiple applications or mission packages. Since these technologies are used on different platforms or in different environments, the program office chose to assess each use as a separate technology. This resulted in a total of 42 critical technologies, 14 of which are currently mature.

The first set of the mine warfare mission package will align with the delivery of the first ship in January 2007. As part of this mission, the MH-60S helicopter is to carry subsystems for either the detection or neutralization of mines. MH-60S and its technologies for mine detection are currently expected to complete testing in fiscal year 2005, after first ship design review for LCS. Its mine neutralization technologies will complete testing in fiscal year 2007, after delivery of the first ship.

The Vertical Take-Off Unmanned Aerial Vehicle is an unmanned helicopter, and will employ the Coastal Battlefield Reconnaissance and Analysis System for detection of mines on the beach. By delivery to LCS in 2006, the platform will be an engineering development model and its payload will still be in testing. The Unmanned Surface Vehicle will be used for all three littoral warfare missions. For mine warfare, it is expected to deploy a mine neutralization system, but neither the vehicle nor its payload will be fully mature by the design review.

The first spirals for antisubmarine and surface warfare packages will align with delivery of the second ship in fiscal year 2008. MH-60R will be used for both these missions. The helicopter and its subsystems are fully mature in the antisubmarine warfare configuration and mostly immature in the surface warfare configuration. It will complete testing for both missions in September 2005.

The Vertical Take-Off Unmanned Aerial Vehicle is a communications relay station for other platforms performing antisubmarine warfare. For surface warfare, it may use the Advanced Precision Kill Weapons System and an Electro-Optical Infrared system. Currently, none of the technologies are fully mature and most will remain in testing by the second ship's design review in August 2005. In its

antisubmarine warfare configuration, the Remote Minehunting Vehicle will use subsystems that are currently immature and will be delivered to LCS as engineering development models. As an antisubmarine warfare platform, the Unmanned Surface Vehicle will carry detection systems that are not yet mature. For surface warfare operations, the program will use a gun system and a missile system. A nonlethal weapon system is also being considered. This vehicle and its technologies are currently immature in all of its mission configurations.

A missile and a gun system for surface warfare will also be on the ship itself, but currently neither of these technologies is fully mature.

### Design Stability

We did not assess design stability due to the competition sensitive nature of the ship's designs.

### Other Program Issues

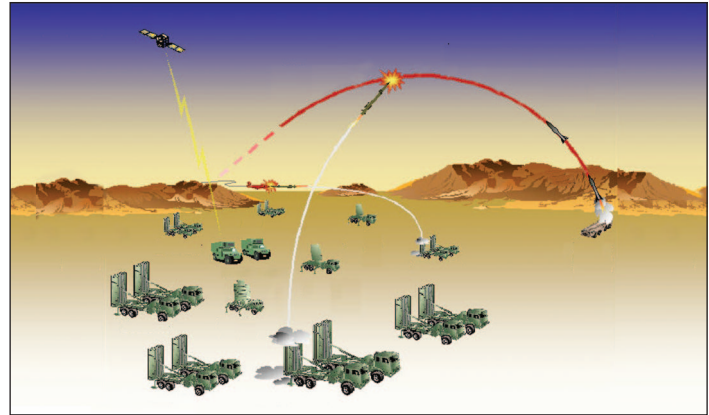
While the MH-60R and MH-60S complete testing in fiscal years 2005 and 2007, respectively, they will be unavailable for deployment with LCS until fiscal year 2009.

### Agency Comments

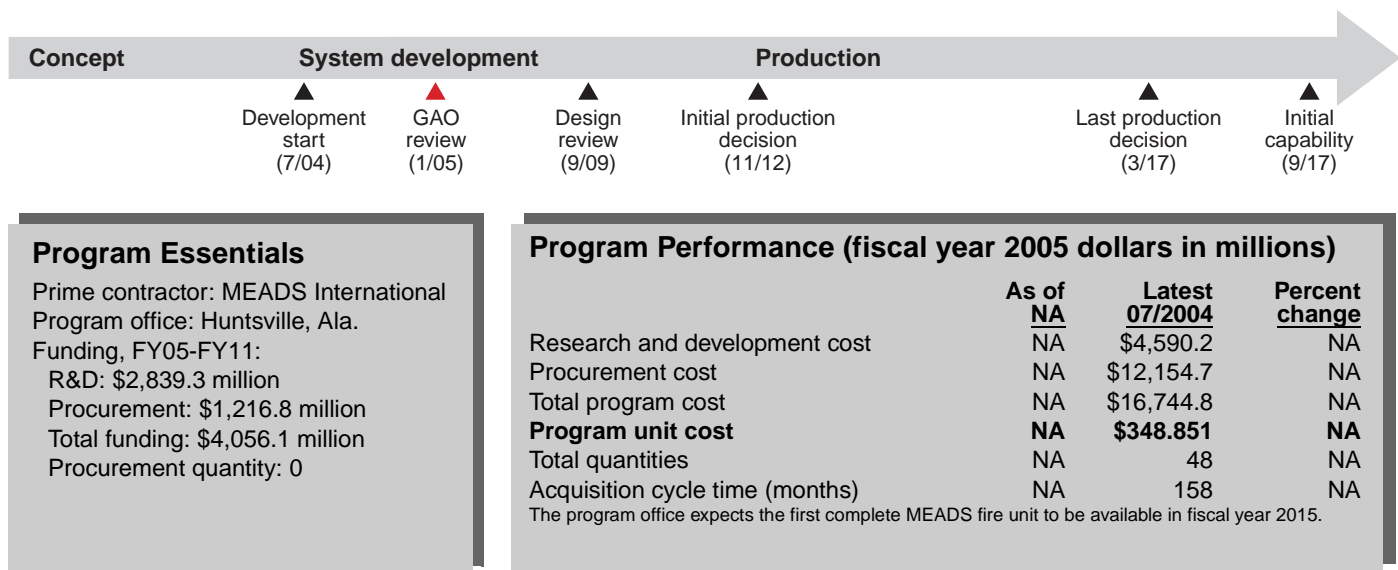
In commenting on a draft of this assessment, the Navy stated that the primary objectives of LCS Flight 0 (the first group of LCS ships) are the harvesting of mission systems to deliver immediate warfighting capability in critical gaps and the design and validation of the modular open system architecture. It also stated that the key to attaining these objectives is the creation of a common interface that enables the independent development of sea frames and mission packages and that the use of this interface is critical for the development and evaluation of sea frames and mission packages to ensure effective interoperability. The result is a total system design that is highly adaptable to changes over the life of the program, but isolates impact to production schedules. The mission package technology risks described in this report are well understood, subject to rigorous risk management including appropriate backup technologies, and generally independent from the successful achievement of LCS Flight 0 key performance parameters.

## Medium Extended Air Defense System (MEADS)

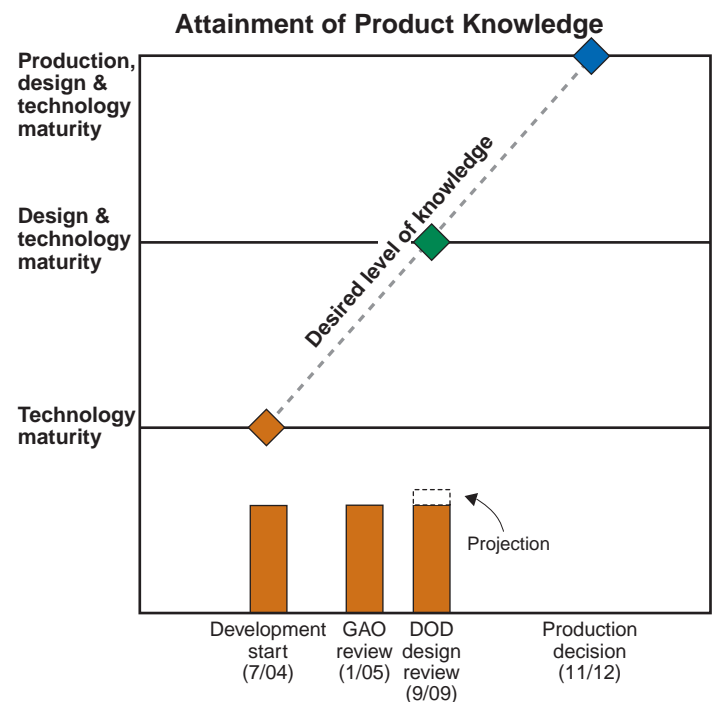
The Army's MEADS is developing a mobile air defense system to protect deployed maneuver forces and critical assets against short- and medium-range theater ballistic missiles, cruise missiles, and air-breathing threats. In 2004, the Army combined management, development, and fielding of the Patriot air defense missile system and MEADS. Although the Army combined the programs, MEADS remains an international development effort among the United States, Germany, and Italy. We assessed the MEADS fire unit portion of the combined program.



Source: MEADS NPO, Lower Tier Project Office.



MEADS began development start in July 2004 with two mature critical technologies, three critical technologies nearing maturity, and one immature critical technology. Program plans call for a system design review in 2009, but program estimates currently project that only one of the six technologies will be more mature at that time than at development start. The program office anticipates that all critical technologies will be fully mature by the start of production in the first quarter of fiscal year 2013.



## MEADS Program

### Technology Maturity

Only two of the six critical technologies—launcher electronics and PAC-3 missile integration—were mature at development start in July 2004. Three other critical technologies—low noise exciter that manages the radars’ frequencies, cooling system for the radars, and slip ring that carries power and coolants to the radars—were nearing maturity. The remaining critical technology—the transmit/receive module that transmits/receives signals for the fire control radar—was immature.

The program office noted that four of the six critical technologies have been demonstrated or employed. According to the office, the MEADS launcher will employ electronics already being developed for the Theater High-Altitude Air Defense (THAAD) and Patriot launcher, and these “common launch electronics” completed design review in May 2003. Likewise, the integration of the Patriot Advanced Capability-3 missile into MEADS will be similar to integrating the missile into the existing Patriot system. Furthermore, the office indicated that a prototype of the low noise exciter met some 90 percent of its performance specifications during the MEADS risk reduction phase that ended in 2004. The office stated that this prototype provided the information on exciter design necessary to take corrective actions in the MEADS development phase. In addition, the office stated that the technology used in the transmit/receive module has been employed in THAAD and demonstrated that MEADS performance requirements could be met. However, the U.S.-developed technology as demonstrated on THAAD is not releasable to the MEADS European partners. The partners are developing their own transmit/receive module for MEADS, but the design has achieved only about 75-80 percent of the performance needed.

The program office projects that the transmit/receive module will increase in maturity by the time of the system design review planned for 2009. The program office expects that the five other critical technologies will be at the same maturity levels as they were at development start. The office expects all critical technologies to be fully mature by the start of production in late 2012. There are no backup technologies for any of the MEADS critical technologies, with the exception of the transmit/receive module.

### Design Stability

We could not assess the design stability of MEADS because the number of releasable drawings and total drawings expected was not available. The program office expects to know the total number of releasable drawings at the design review in 2009.

### Other Program Issues

The program has adopted an incremental acquisition approach. There are three increments, with the first beginning in 2008, another in 2010, and the final in 2013. The program office plans for each increment to introduce new or upgraded capability into the program. The Army expects MEADS to achieve initial operational capability in 2017 with four units.

The contract award for the United States, Italy, and Germany to proceed into design and development together has been delayed by about 9 months. The Army originally expected the contract award to occur in June/July 2004, but the award did not occur. In September 2004, the United States and Italy signed a memorandum of understanding to proceed to design and development, and a letter contract was awarded to initiate that phase. The contract has a 6-month period of performance, which coincides with the March 2005 date when the Army expects Germany to sign the memorandum.

### Agency Comments

The Army generally concurred with this assessment. It indicated that we addressed critical technologies that were already areas of intense management focus. Additionally, it stated that the transmit/receive module’s maturity assessment changed due to international memorandum of understanding negotiations and U.S. National Disclosure Policy that changed the source of the modules. The Army also noted that it still expects all technologies to be fully mature by production and further stated that there are risk mitigation plans for the maturing technologies as well as alternate backup technologies now identified for the transmit/receive module. Additionally, the Army stated that, at the design review in 2009, the design work in the critical technologies will be at the maturity level required to fabricate system prototypes and thus demonstrate system capabilities.

### GAO Comments

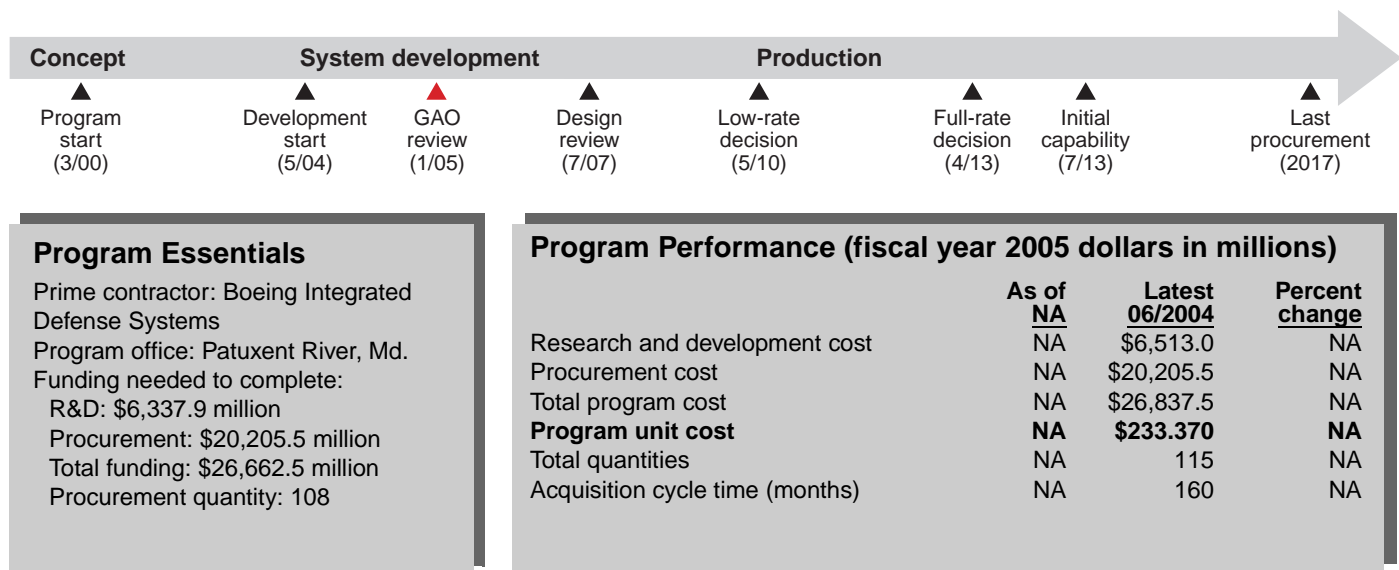
The MEADS Program Office clarified that the transmit/receive module’s maturity had decreased and we revised our assessment accordingly.

## Multi-mission Maritime Aircraft (MMA)

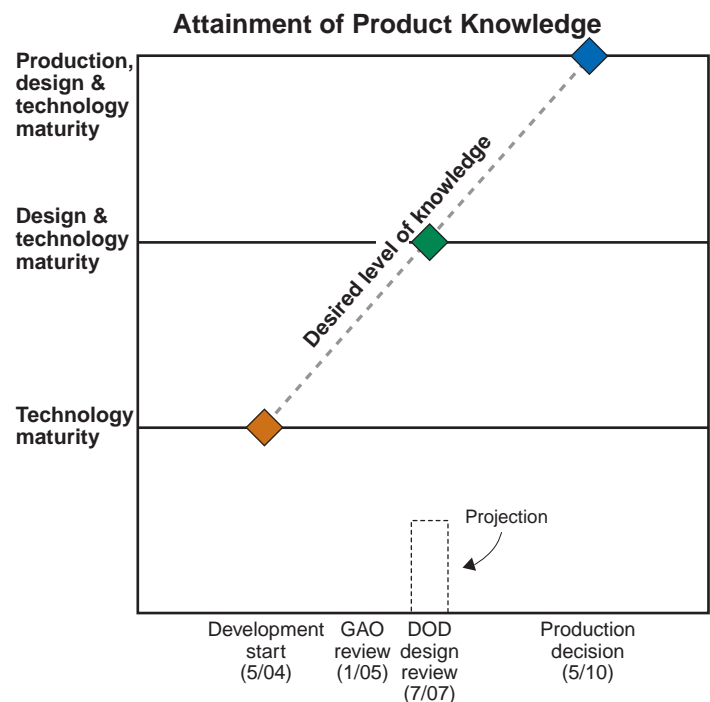
The Navy's MMA is one element of the Broad Area Maritime Surveillance (BAMS) family of systems, along with the BAMS Unmanned Aerial Vehicle (UAV) and Aerial Common Sensor programs. The MMA is manned, and it will sustain and improve armed maritime and littoral intelligence surveillance and reconnaissance capabilities of the U.S. Navy. The primary roles of the MMA are persistent antisubmarine and antisurface warfare. It is the replacement for the P-3C Orion. DOD is discussing international partner participation in the program.



Source: Boeing - Integrated Defense Systems, © 2004 The Boeing Company.



The MMA program entered development with none of its four critical technologies mature. According to the program office, these technologies will be demonstrated in a relevant environment by design review and tested in an operational environment by the production decision. The system's technology maturity will be demonstrated at least 3 years later than recommended by best practice standards. However, the program has identified mature backup technologies.



## MMA Program

### Technology Maturity

None of the 4 critical technologies—integrated rotary sonobuoy launcher, electronic support measures digital receiver, data fusion, and acoustic algorithms—are mature. These technologies have not moved beyond the laboratory environment. For three of the technologies, the components have not been integrated into a prototype system. The program expects the four technologies to be demonstrated in a relevant environment by design review in July 2007 and tested in an operational environment by the production decision in May 2010. The system's technology maturity will be demonstrated at least 3 years later than recommended by best practice standards.

The program office and the contractor developed maturation plans and identified mature backup technologies for each of the critical technologies. According to program officials, the MMA would lose some capabilities but still meet its minimum system requirements if it used these backups. For example, one of the biggest technology challenges for the MMA identified by program officials is the electronic support measures digital receiver. This technology exists as a prototype and has been demonstrated in a high fidelity laboratory environment. The program is leveraging the digital receivers currently in development on the EA-18G program. If the EA-18G digital receiver program is unsuccessful, the program will have to use legacy analog off-the-shelf receivers, which would prevent them from gaining an increased sensitivity for certain signals.

The four technologies we assessed were identified in the MMA's technology readiness assessment. The program evaluated six other technologies but decided they were not critical because they had already been demonstrated in a relevant or operational environment.

### Design Stability

We did not assess design stability as the number of releasable drawings is not yet available.

### Other Program Issues

In addition to its primary roles of antisubmarine warfare and antisurface warfare, the MMA shares the persistent intelligence surveillance and reconnaissance (ISR) role with the BAMS UAV. The

BAMS UAV program will not start development until fiscal year 2005, and if it does not develop as expected, the MMA program is the fall back to perform its mission. According to program officials, in order to fulfill this mission, the Navy would have to procure 14 additional aircraft by 2018, increasing the overall cost of the program. If the MMA fails to develop as expected or experiences schedule slippage, the Navy will have to rely on its aging P-3C Orion fleet, which, according to DOD, is plagued by serious airframe life issues, poor mission availability rates, high ownership costs, and limited system growth capacity.

The MMA program is discussing international participation with Australia, Canada, and Italy for the development phase of the program. This participation could include both the MMA and BAMS UAV programs. DOD expects to benefit from improved interoperability, strengthened allies, and lower production costs due to increased sales. Program officials stated that they are incorporating lessons learned from the Joint Strike Fighter international program, particularly in managing partner expectations regarding technology transfer.

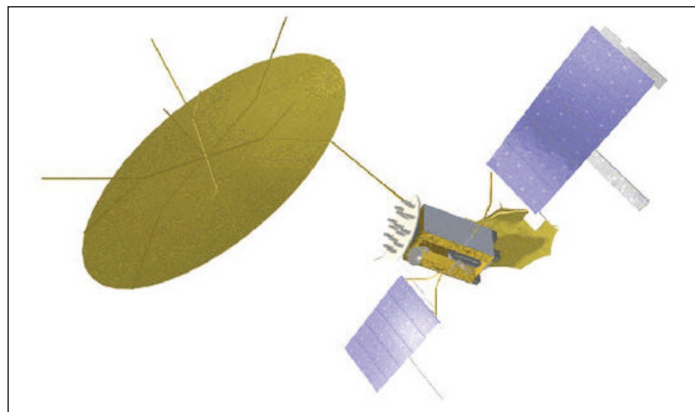
### Agency Comments

In commenting on a draft of this assessment, the Navy generally concurred with our characterization of the MMA program. It stated that the four critical technologies are tracking along their current maturation plans and that it is confident that by design readiness review, these technologies will be demonstrated in a relevant environment. It noted that these four technologies are being matured through the MMA risk management process.

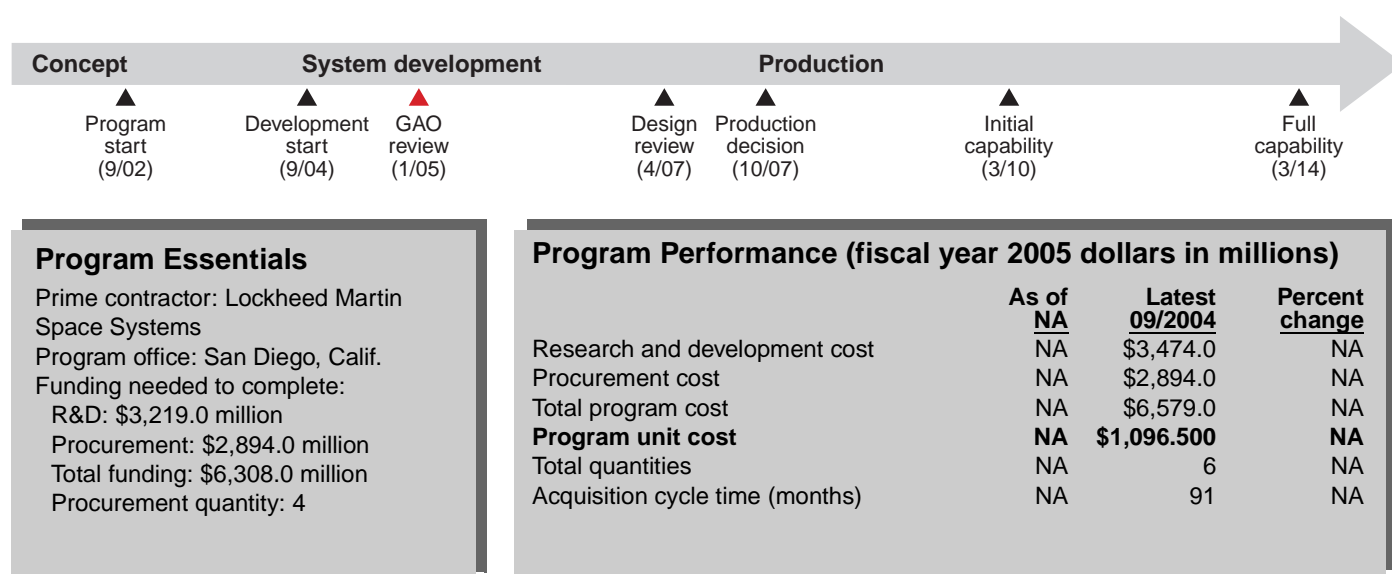
With regard to the BAMS mission, the Navy stated that an analysis of alternatives conducted in May 2002 concluded that 14 additional aircraft would have to be in place by 2018 to replace the Legacy P-3 ISR requirements that were allocated to the BAMS UAV. It further stated that since that time, a BAMS UAV Operational Requirements Document has been approved that identified additional UAV specific missions and requirements that were not considered in the May 2002 analysis of alternatives. It noted that there is no current completed analysis that encompasses how many aircraft, based on new approved BAMS UAV operational requirements document, would be required if the BAMS UAV does not develop as expected.

## Mobile User Objective System (MUOS)

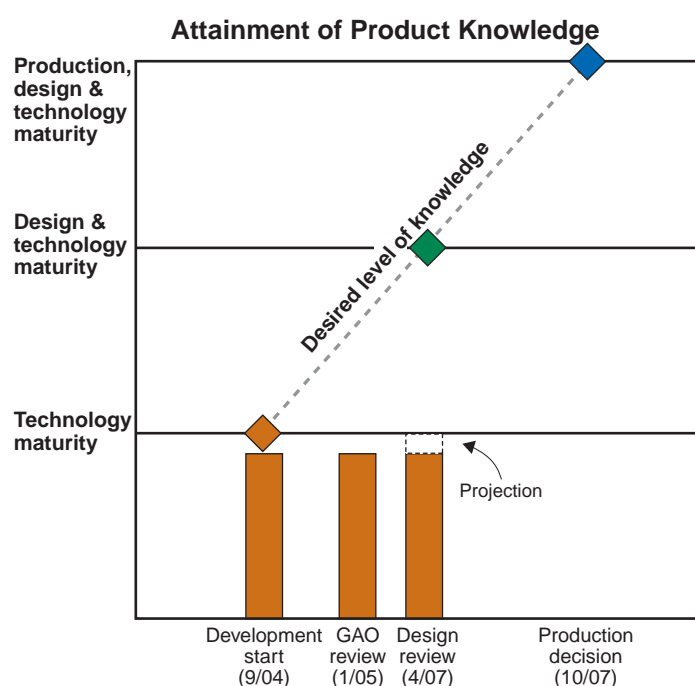
The Navy's MUOS, a satellite communication system, is expected to provide low data rate voice and data communications capable of penetrating most weather, foliage, and manmade structures. It is designed to replace the Ultra High Frequency (UHF) Follow-On satellite system currently in operation and provide support to worldwide, multiservice, mobile, and fixed-site terminal users. MUOS consists of a network of advanced UHF satellites and multiple ground segments. We assessed both the space and ground segments.



Source: Artist rendering of MUOS satellite, Lockheed Martin.



In September 2004 the MUOS program was authorized to begin development. The program currently has eight of nine critical technologies mature. The remaining technology is projected to be mature by April 2007 in time for the critical design review. The program intends to order long lead items for the first two satellites before achieving a stable design. This early procurement could lead to rework causing cost increases and schedule delays if relevant designs change prior to critical design review. In addition, the MUOS development schedule remains compressed, posing several risks to the program.



## **MUOS Program**

### **Technology Maturity**

Eight of nine critical technologies were mature at the development start decision in September 2004. The remaining technology, a new cryptographic chip, is expected to be mature by the time the program reaches its critical design review in April 2007. A mature backup technology exists for this chip in the event that it fails to mature in time. However, the use of the backup technology would increase the vulnerability to attacks on the transmissions of signals that are used to ensure the satellites remain properly placed in their orbits around the earth.

### **Design Stability and Production Maturity**

The MUOS program intends to procure long lead items for the first two satellites before achieving a stable design. The September 2004 development start decision authorized the program to procure long lead items for these satellites. According to the program office, ordering of long lead items is to begin in 2005 after segment-level preliminary design reviews, but well before critical design review in April 2007. This early procurement could lead to rework if relevant designs change prior to critical design review, causing program cost increases and schedule delays. According to the program office, long lead procurement is necessary to preserve the program schedule and delaying such procurement until after critical design review would cause the program schedule to slip. It also noted that the dollar amount of long lead procurement prior to critical design review is not large, at \$65.9 million.

In addition, the program office has yet to determine the total number of design drawings needed to build the satellites. According to the program office, the development contract requires completion of 90 percent of design drawings as a condition of conducting critical design review.

### **Other Program Issues**

DOD delayed the first MUOS satellite launch as well as its initial operational capability by 1 year to fiscal year 2010. Despite the delays, the MUOS schedule remains compressed and poses several risks to the program. For example, initial operational capability is to be declared before on-orbit operational testing is to occur. Usually, the results of such testing are used to support decisions for declaring operational

capability and identifying problems that may necessitate design changes. Furthermore, the time period between the critical design review and the first satellite launch is shorter for the MUOS program, at about 2.7 years, than that of the previous UHF Follow-On program, at about 3 years. This schedule comparison is important given the significant leap in increased capability that MUOS is expected to provide. While the UHF Follow-On program increased communications capability by up to a factor of 3, the MUOS program is expected to increase communications capability by a factor of 20. The program office, however, considers the development of the satellite to be low risk. In addition, program officials stated that the initial operational capability was changed to mean initial MUOS on-orbit capability, and initial operational capability would be declared after on-orbit operational testing takes place.

In addition, an independent program assessment states that the program is schedule-driven primarily because of the software development effort. According to the program office, software development for the MUOS ground segment represents one of the highest risks to the program due to the size and complexity of the contractor's design. The program office stated that the ground software segment is to be developed incrementally to mitigate schedule risk.

### **Agency Comments**

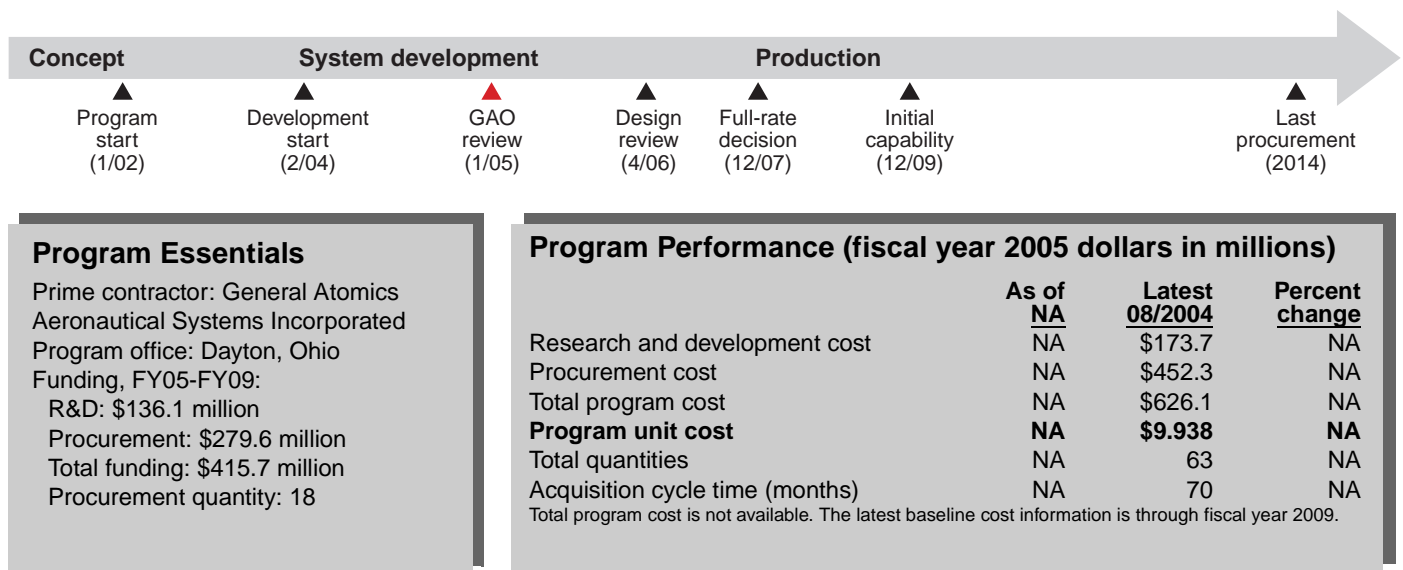
In commenting on a draft of this assessment, the Navy provided technical comments, which were incorporated where appropriate.

## MQ-9 Predator B

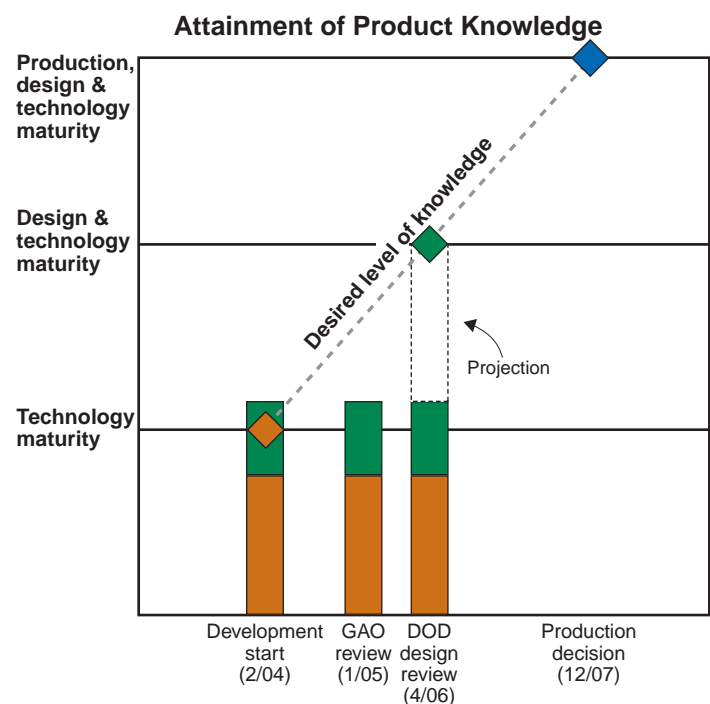
The Air Force's MQ-9 Predator B is a multirole, medium-to-high altitude endurance unmanned aerial vehicle system capable of flying at higher speeds and higher altitudes than its predecessor the MQ-1 Predator A. The Predator B is designed to provide a ground attack capability and will employ fused multispectral sensors to find and track small ground mobile or fixed targets. As envisioned, each Predator B system will consist of four aircraft, a ground control station, and a satellite communication suite. We assessed only the air vehicle.



Source: General Atomics-Aeronautical Systems, Incorporated.



The Predator B entered system development in February 2004 with three of its four critical technologies mature. The fourth, needed for weapons launch, has not matured as expected. The Air Force expects this technology to be ready in August 2005—a slip of 13 months. No backup technology is available. If this technology fails to mature, it will prevent the Predator B from performing its primary mission to destroy enemy targets. The program recently changed to incrementally develop versions of the Predator B. The Air Force believes most drawings for increment one will be complete by the 2006 critical design review. The program has also concurrently started to produce Predator B aircraft, and operational testing is not scheduled to be complete until 2007 when one-third of them will be on contract. Concurrency increases the risk of redesign and need to retrofit already acquired system.



## **Predator B Program**

### **Technology Maturity**

Three of the Predator B's four critical technologies, the synthetic aperture radar, the multispectral targeting system, and the air vehicle, are fully mature. The avionics subsystem technology designed to integrate and store data necessary to launch munitions is still being evaluated in a laboratory environment. It is expected to be ready by August 2005, a 13-month schedule slip. No backup technology is available. If this critical technology fails to mature, it will prevent the Predator B from performing its primary mission to destroy enemy targets. The Air Force plans to retrofit these and other air vehicles that are under production once this capability has been fully demonstrated.

### **Design Stability**

Subsequent to Milestone B approval in February 2004, the program office was directed by Headquarters Air Force to develop Predator B in three increments. DOD is in the process of defining the increments. The program office expects 94 percent of the expected increment one drawings to be completed by the April 2006 critical design review, which has been delayed about 7 months since our last report. Program officials acknowledge that additional drawings will be needed for subsequent increments. Design changes and modification of drawings are likely to occur late in development, increasing the need to retrofit already acquired systems.

### **Production Maturity**

Program officials said the contractor does not plan to use statistical process controls to ensure product quality. Instead, they plan to use other quality control measures such as scrap, rework, and repair to track product quality. Also, initial operational testing of increment one, which is to demonstrate a product is ready for production, is not scheduled to be complete until September 2007. Testing for remaining increments has not been determined.

### **Other Program Issues**

In February 2004, Headquarters Air Force directed the program office to quickly field an interim combat capability to the warfighter by fiscal year 2006. This delayed the start of the system development and demonstration phase by 9 months to

November 2004. However, the Air Force is already concurrently on contract to produce 15 Predator Bs. The decision to make Predator B an incremental development program has also extended the completion of development by nearly 4 years. An incremental approach is the preferred approach to weapon acquisitions. However, the Air Force does not plan to have formal decisions approving entry into development for subsequent increments as required by DOD acquisition policy. To reduce the risks of concurrently developing and producing Predator Bs, the program office lowered annual buy quantities and extended production 5 years. The estimated program completion date is now 2014.

The Air Force is still evaluating a variety of lightweight munitions for use on the Predator B. The Air Force is also weighing the possibility of adding new system capabilities such as launching very small or micro unmanned aerial vehicles from the Predator B and equipping it with air-to-air missiles.

### **Agency Comments**

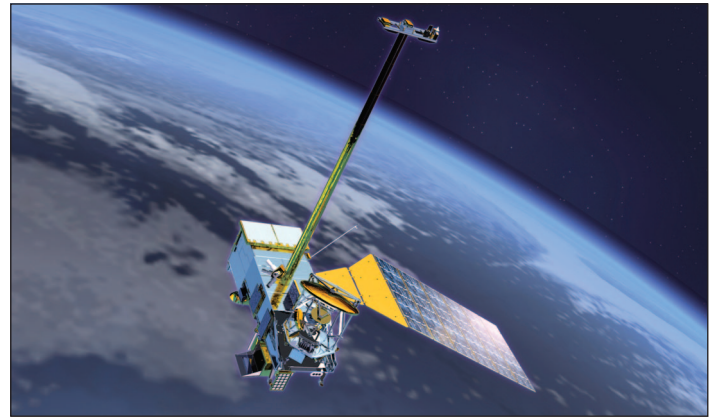
In commenting on a draft of this assessment, the Air Force disagreed with our evaluation of the Predator B development risks. It stated that the stores management system technology is mature and that the system is being tested. It also noted that the existing weapons release system provides a backup capability. It also disagreed with our assessment that the Predator B development had been extended by 4 years. It stated that, as planned, the initial operational capability will follow the completion of the first increment in December 2009. Future increments are to be determined. Before starting future increments, the Air Force stated that proper approval will be obtained from the milestone decision authority. Also, its acquisition plan has phased production rates to the development effort, and the increased concurrent production before operational testing has been driven by congressional actions.

### **GAO Comments**

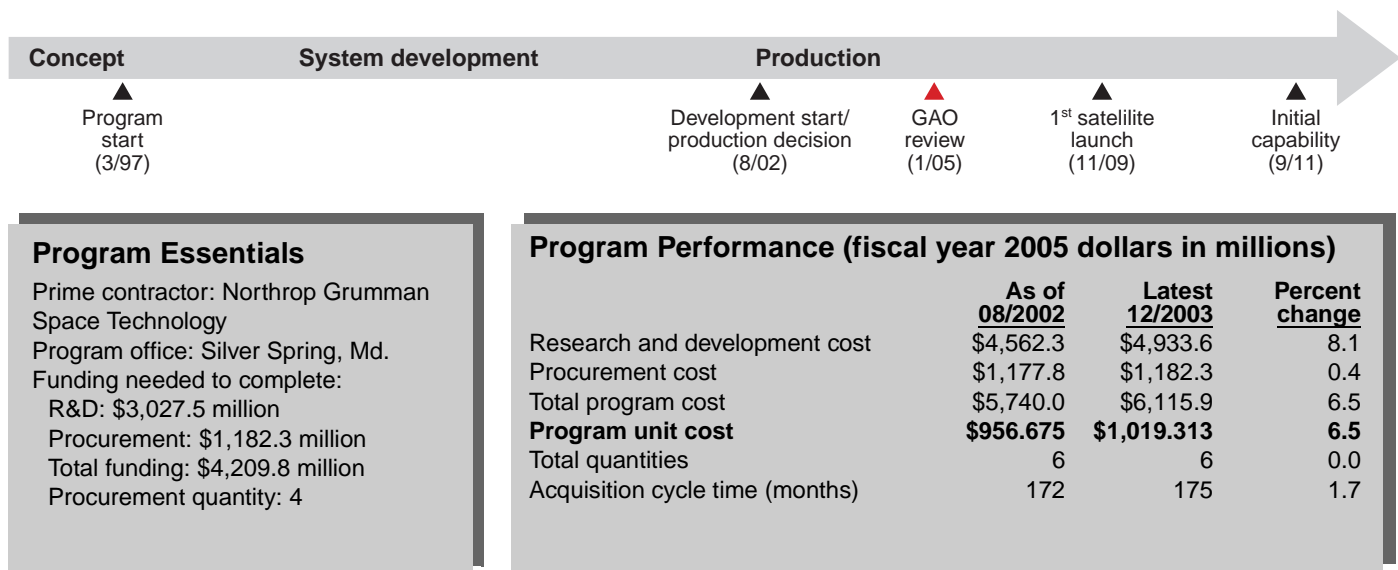
The program planned to deliver the full capability Predator B in 2006, but due to acquisition approach changes the full capability Predator B is now scheduled for delivery in 2010—a 4 year extension.

## National Polar-orbiting Operational Environmental Satellite System (NPOESS)

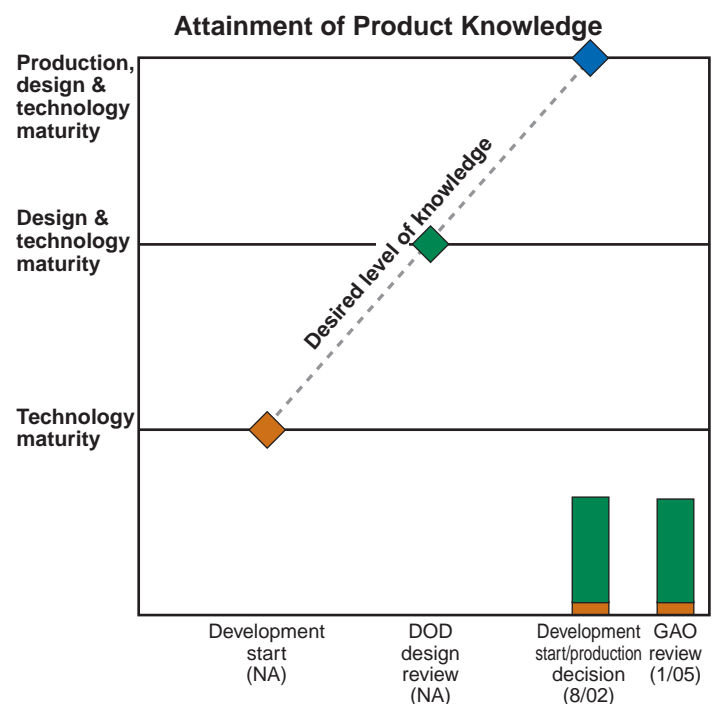
NPOESS is a triagency National Oceanic and Atmospheric Administration (NOAA), DOD, and National Aeronautics and Space Administration (NASA) satellite program to monitor the weather and environment through the year 2020. Current NOAA and DOD satellites will be merged into a single national system. The program consists of five segments: space; command, control, and communications; interface data processing; launch; and field terminal software. We assessed all segments.



Source: NPOESS Integrated Program Office.



In August 2002, the NPOESS program committed to the development of satellites with operational capability without having demonstrated technology maturity or design stability. Only 1 of its 14 critical technologies is mature. The program expects that all but 4 of these will be mature by the design review in April 2006. The program has released about half of its design drawings and expects to complete about 94 percent by design review. It is not collecting statistical process control data to assess production maturity because of the small number of units being produced. At present, the program office considers the three critical sensors to be key program risks because of technical challenges. Due to a recent program restructuring, the program office estimates that the cost of the program will increase to \$8.1 billion.



## **NPOESS Program**

### **Technology Maturity**

Only 1 of the program's 14 critical technologies were (and currently are) mature at the production decision in August 2002. This is less than reported last year due to the program office's more accurate application of the technology standards. The program projects that all but 4 of the technologies will be mature by the design review in 2006.

The program undertook the NPOESS Preparatory Project, a demonstration satellite, to reduce risk and provide a bridging mission for NASA's Earth Observing System. This satellite, scheduled for launch in 2006, is planned to demonstrate three critical sensors in an operational environment. This will provide data processing centers with an early opportunity to work with sensors, ground controls, and data processing systems and allow for incorporating lessons learned into the satellites. The three critical sensors are experiencing continued technical problems and schedule delays. The program office considers these sensors as top program risks.

### **Design Stability**

In August 2002, the program committed to the development of two satellites with operational capability before achieving design stability or production maturity. Program officials indicated that about 50 percent of the design drawings were released to manufacturing and expects to release about 94 percent by the design review in 2006.

### **Production Maturity**

We could not assess production maturity because, according to the program office, it does not collect statistical process control data due to the small number of units to be built. However, the ground segment contractor uses various metrics such as schedule and cost performance indices, rework percentages, and defect containment to ensure production is proceeding as planned. According to the program office, monthly reviews of these metrics reveal acceptable results.

### **Other Program Issues**

In 2002, DOD extended the launch date of one of its legacy meteorological satellites to 2010, delaying the need for NPOESS. DOD and NOAA thus reduced their NPOESS funding by about \$144 million through

fiscal year 2007 and the program delayed the launch of the first satellite 7 months, to November 2009.

The recent funding reductions prompted a restructuring of the NPOESS program. The program office estimates that the cost will increase to \$8.1 billion. This increase reflects changes to the contract and increased program management costs. The program office reports that the increases include costs associated with extending the development schedule, increased sensor costs, and additional funds needed for mitigating risks.

The program office is planning to present a new cost estimate to its executive oversight committee in January 2005 to ensure the program is adequately funded. Other factors could further affect the revised cost and schedule estimates. Specifically, the contractor is not meeting expected cost and schedule targets of the new baseline because of technical issues in the development of key sensors.

### **Agency Comments**

In commenting on a draft of this report, the program office stated that it lowered its technologies' maturity levels in September 2004 at our request. Program officials also commented that since the government can no longer afford full-up research and development satellites, few instruments can attain technology maturity and systems cannot achieve design stability or production maturity prior to entering full-scale development. The program office stated that it spent 5 years in the Preliminary Design and Risk Reduction phase driving down sensor and system risk, thereby significantly increasing the technology and sensor design maturity before entering the Acquisition and Operations phase in August 2002. It also noted that the current instrument problems highlighted above result from design/manufacturing process issues, which are not related to the listed critical technologies.

### **GAO Comments**

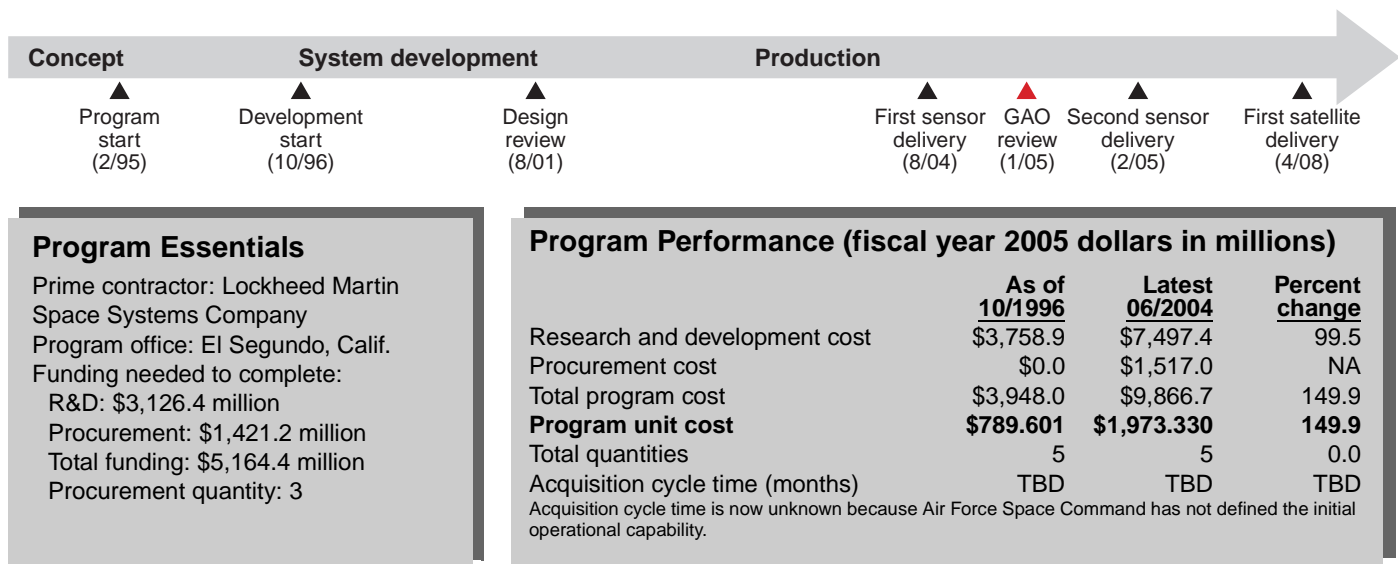
The NPOESS program's technology maturity levels were lowered because the program office more accurately applied the technology standards. In addition, these standards do not require the launch into space of a full-up research and development satellite in order to achieve full maturity. Rather, a representative model demonstrating the full functionality of the subsystems in a relevant environment is sufficient.

## Space Based Infrared System (SBIRS) High

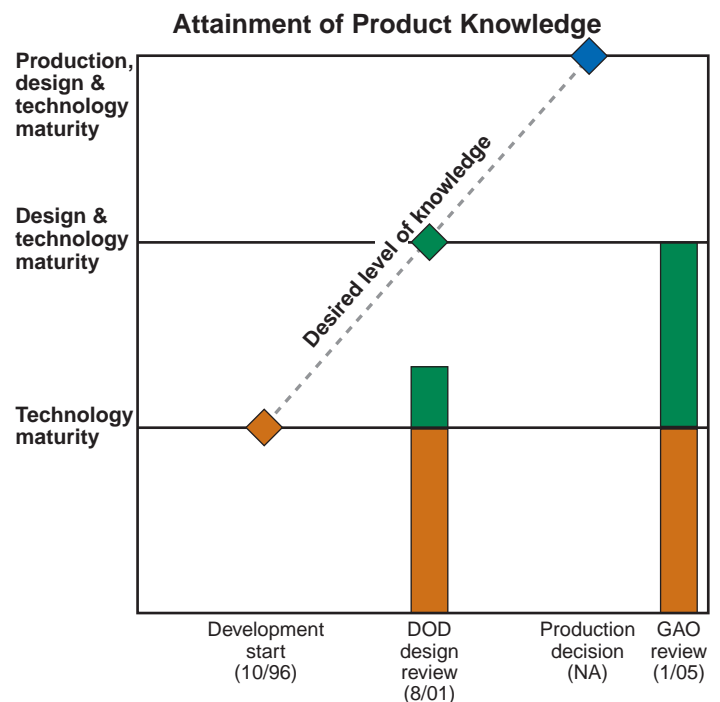
The Air Force's SBIRS High program is a satellite system intended to provide missile warning information and to support the missile defense, technical intelligence, and battlespace characterization missions. It also is intended to replace the Defense Support Program and to consist of four satellites (plus one spare) in geosynchronous earth orbit (GEO), two sensors on host satellites in highly elliptical orbit (HEO), and associated fixed and mobile ground stations. We assessed the sensors and satellites only.



Source: Lockheed Martin Space Systems Company.



The SBIRS High program's critical technologies have demonstrated acceptable levels of maturity after many years of difficult development. The design is now mature since approximately 98 percent of the expected design drawings have been released. Production maturity could not be determined because the contractor does not collect statistical control data. In August 2004 the contractor delivered the first payload (the HEO 1 sensor) after a delay of 18 months. This created additional delays and cost increases. As a result, the program is again being replanned.



## **SBIRS High Program**

### **Technology Maturity**

The SBIRS High program's three critical technologies—the infrared sensor, thermal management, and on-board processor—are mature. Program officials indicated that the hardware was tested in a thermal vacuum chamber under expected flight conditions. These technologies were not mature at the start of development.

### **Design Stability**

The design of SBIRS High was not stable at the critical design review in August 2001 since only 30 percent of the expected design drawings had been released at that time. The design is now stable with about 98 percent released.

Design stability has been an issue for SBIRS High. The first HEO sensor was delivered in August 2004 after a delay of 18 months due to excessive electromagnetic interference (radio waves emitted by the sensor's electronics that interfered with the host satellite). The program office reports that it applied the knowledge gained from the design problems on this sensor to the second HEO sensor, which is now due for delivery in February 2005—a 13-month delay from the restructured schedule. Initial testing of the second sensor revealed one electromagnetic interference issue. The program office anticipates the approval of a waiver to this deviation.

### **Production Maturity**

We could not assess the production maturity of SBIRS High because the contractor does not collect statistical process control data. However, the program office tracks and assesses production maturity through detailed monthly manufacturing and test data and monthly updates on flight hardware qualifications. In addition, the program office recently assigned detailed entrance criteria to all major manufacturing and test events. These criteria must be fully satisfied prior to program office approval to enter the specific event. According to the program office, this new “event-driven” philosophy will significantly improve insight into the maturity of the production process.

### **Other Program Issues**

The delayed delivery of the first HEO sensor affected cost and schedule for the remainder of the program. For example, resources needed for the second HEO sensor and GEO satellites were instead used on the first HEO sensor. The deliveries of the first two GEO satellites have now each been delayed by over a year (to April 2008 and April 2009).

In May 2004, the program incurred a second Nunn-McCurdy breach (10 U.S.C. 2433), this time at the 15 percent threshold. Since program delays and the extension of the contract through 2011 yielded a substantial funding shortfall, Congress increased the SBIRS High fiscal year 2005 budget by \$91 million. The program office reports that future risks are being mitigated by addressing high-risk elements earlier in the development phase as well as earlier and more robust testing. It also plans to convene an independent review team in early 2005 to assess the program's progress and future risks.

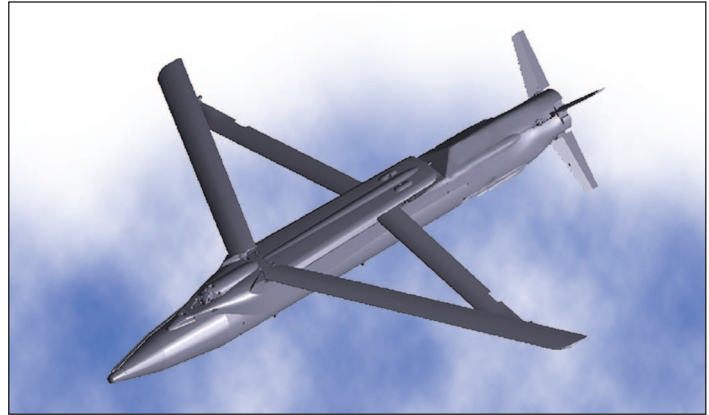
Because of the lag time between the procurement of the first two GEO satellites and the last three, the Air Force is able to consider upgrading the on-board processors for the GEO satellites 3-5. A revised acquisition program baseline will be submitted in March 2005 after a decision on this upgrade is finalized and the cost impact is determined.

### **Agency Comments**

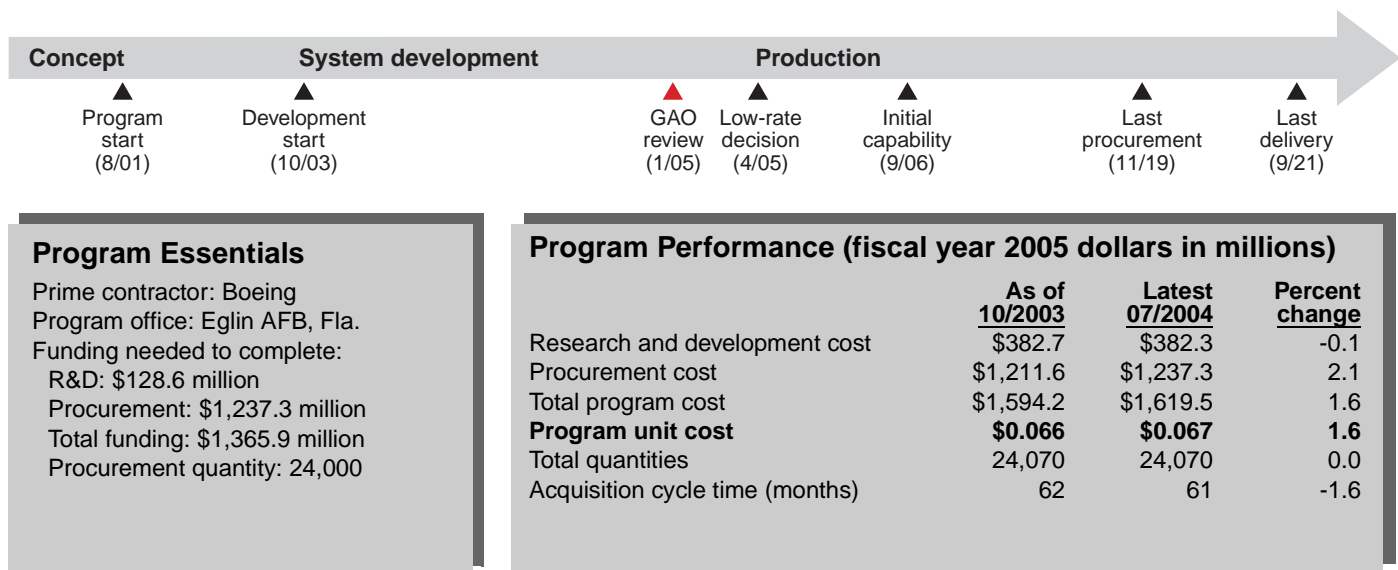
In commenting on a draft of this report, the Air Force stated that the February 2005 delivery of the second HEO sensor is well before the need date of mid-June 2005. It also noted that the GEO satellite's signal processor assembly power supply and the common gyro reference assemblies were integrated onto the payload structure (both are key steps toward the payload's first thermal vacuum test) and that GEO spacecraft testing has been successful in the early identification and mitigation of hardware/software integration issues before they become schedule critical path concerns. It also commented that the Defense Support Program-capable Multi-Mission Mobile Processors are in test and are on track for operational certification by December 2005 and that initial SBIRS High support to the Missile Defense Agency mission is in place.

## Small Diameter Bomb (SDB)

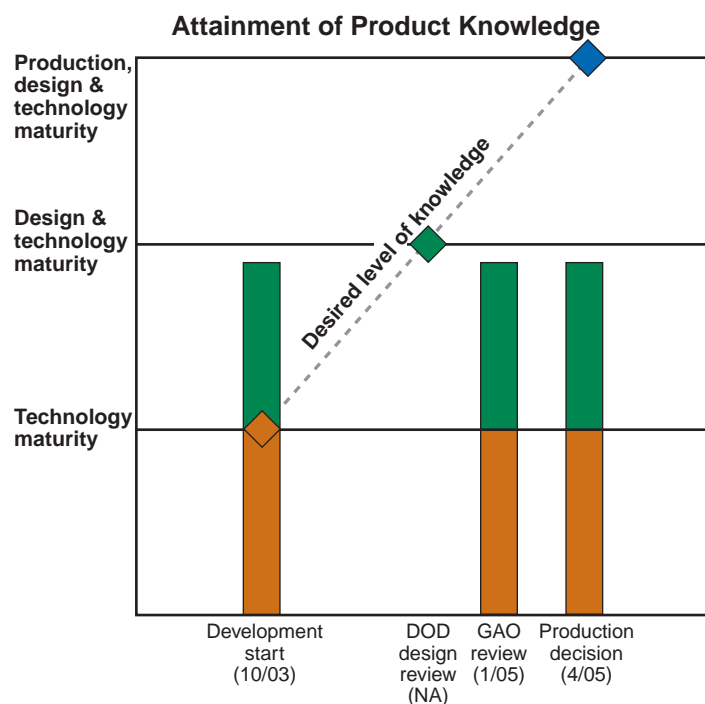
The Air Force's SDB is a small autonomous, conventional, air-to-ground, precision bomb able to strike fixed and stationary targets. The weapon will be installed on the F-15E aircraft and is designed to work with other aircraft, such as the F/A-22. Potential follow-on capabilities, such as precision strike against moving targets, are being considered.



Source: The Boeing Company, St. Louis, Missouri.



The six critical technologies for the SDB appear mature, and the design is stable. The program office held the design review prior to starting system development and, although data were not collected, the program maintains that the contractor released over 90 percent of the production drawings. In 2004, the program began a test program, which combines developmental, live fire, and operational testing, in an effort to decrease time spent in system development. Although the first three flight tests were successful, this concurrent approach may increase program risks. A low-rate production decision is expected to be made in April 2005.



## **SDB Program**

### **Technology Maturity**

The program office assessed all six critical technologies for the SDB as mature. The technologies are the airframe, the Anti-Jam Global Positioning System, the fuze, the Inertial Navigation System, the carriage, and warhead. Program officials stated that many of the program's critical technologies were demonstrated in a free-flight environment. They also stated that they have flight-tested the system with the properly sized components.

### **Design Stability**

The design review was held prior to the start of system development and, although data were not collected, the program office maintains that Boeing released over 90 percent of the production drawings. According to the program office, although the contractor has ultimate responsibility for the weapon system and has given the government a 20-year "bumper to bumper" warranty, the program office has insight into the contractor's configuration control board process and all changes are coordinated with the government.

The SDB program began a program of developmental, live fire, and operational testing in 2004. This combined testing approach is designed to eliminate or reduce redundant testing. However, this process could expose the program to additional risk of design changes, as there may be more concurrency between system developmental and operational tests than there would be under a traditional test program. As of the date of this review, 3 of 16 planned flight tests had been conducted, each meeting its objectives. These flight tests were conducted with live fuzes but not with live warheads. Eleven of the 16 flight tests are planned to be conducted prior to the low-rate production decision point.

### **Production Maturity**

We could not assess production maturity because statistical process control data were not available. In developing the SDB, Boeing used many key components that are common with the Joint Direct Attack Munition (JDAM). The SDB production line will be colocated in the same facility used to produce the JDAM. According to program officials, the production line layout is very similar to the

processes currently used for the JDAM. As of the date of this review, no critical manufacturing processes that impact the critical system characteristics had been identified. A low-rate production decision is expected to be made in April 2005.

### **Agency Comments**

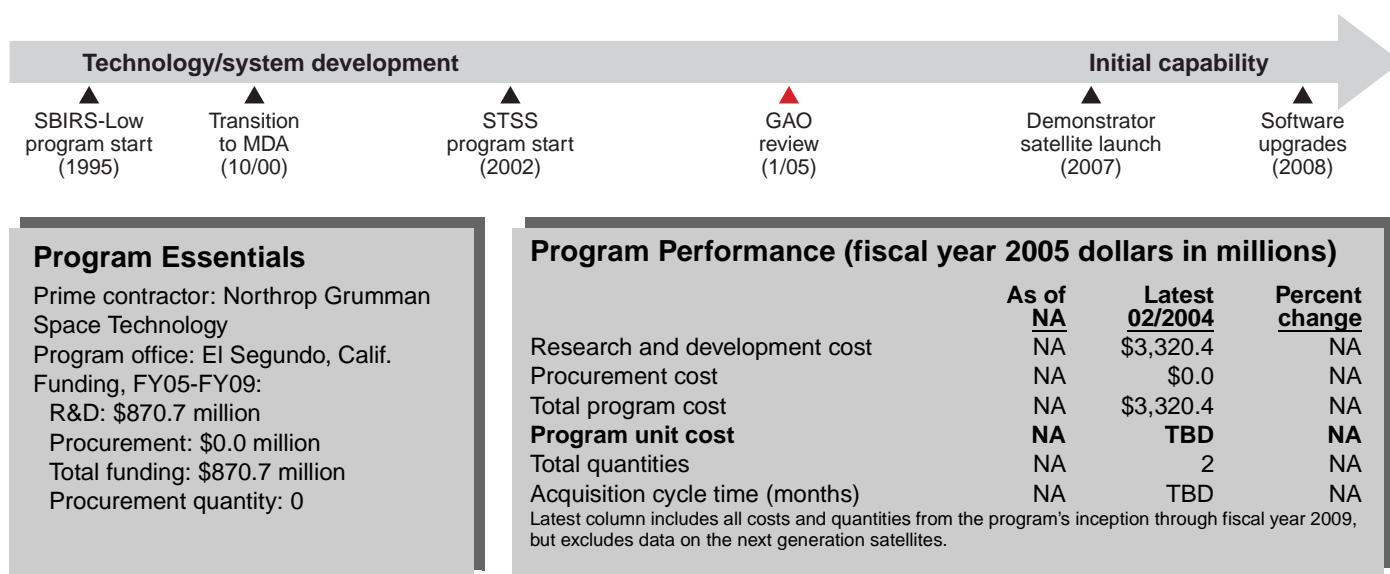
In commenting on a draft of this assessment, the Air Force concurred with the information presented and provided technical comments, which were incorporated as appropriate.

## Space Tracking and Surveillance System (STSS)

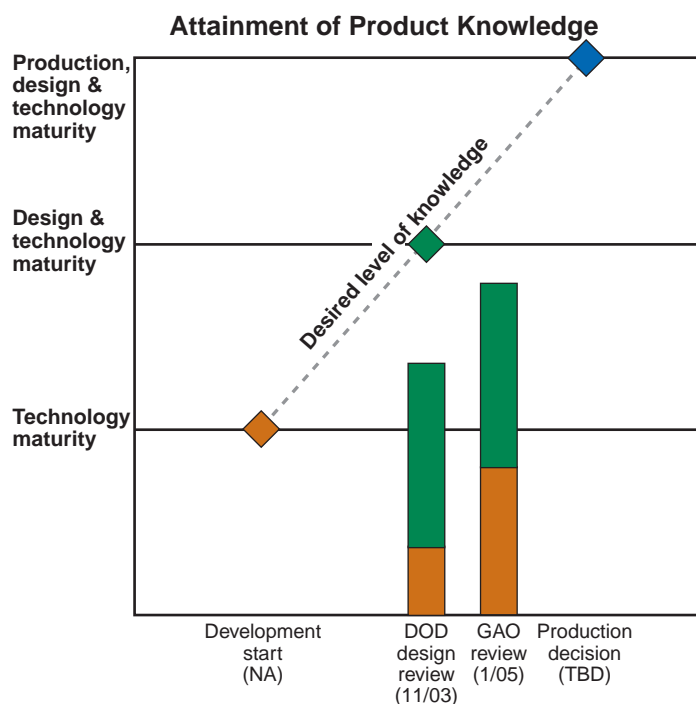
MDA's STSS element is being developed in incremental, capability-based blocks designed to track enemy missiles throughout their flight. The initial increment is composed of two demonstration satellites built under the Space Based Infrared System Low program. MDA plans to launch these satellites in 2007 to assess how well they work within the context of the missile defense system. MDA is also studying improvements to the STSS program, and it will be building next generation satellites. We assessed the two demonstration satellites.



Source: STSS Program Brief.



Four of the STSS program's five critical technologies are mature, and the remaining technology is expected to reach maturity in March or April 2005. The STSS design appears stable, with all drawings released to manufacturing. However, until all STSS technologies demonstrate maturity, the potential for design changes remains. The program is currently in the process of conducting system level assembly, integration, and testing activities and software development. Until that work is complete, certain risk areas, such as payload hardware and software integration, will remain. Additionally, a number of systemic quality and systems engineering problems with the payload have persisted. Despite these issues, the program office still expects early delivery and launch of the satellites.



## **STSS Program**

### **Technology Maturity**

Four of five critical technologies—satellite communication cross-links, on-board processor, acquisition sensor, and track sensor—are mature. The acquisition sensor reached maturity in October 2004 (a month later than reported last year) when the thermal vacuum testing was completed. The track sensor reached maturity in December 2004 when the payload for the first satellite completed thermal vacuum testing, which is 3 months later than reported last year. The single-stage cryocooler will be mature when the payload for the first satellite completes thermal vacuum testing in March or April 2005—about 15 months earlier than reported previously. Last year the program had a sixth technology, the two-stage cryocooler, but it is no longer considered critical and will not be used on the first increment of the STSS program.

### **Design Stability**

The STSS program's design is stable, with all drawings released to manufacturing. When the STSS program started in 2002, design drawings and the satellite components for the partially built satellites from the Space Based Infrared System Low effort were released to manufacturing. By the time STSS went through its design review in November 2003, the program office had released all subsequent design drawings. However, until the maturity of the STSS technologies has been demonstrated, the potential for design changes remains.

### **Other Program Issues**

The STSS program is in the process of completing the assembly, integration, and testing of the satellite components and software development. Until that work is complete, certain risk areas will remain. Some of these include complex infrared payload hardware and software integration; completion of the ground segment and infrared sensor software development and testing; modifications to the tracking sensor, system integration and testing; and handling issues related to parts obsolescence.

In addition, the payload subcontractor has had a number of systemic quality and systems engineering problems. These problems have continued for the last year and have contributed to some cost and schedule overruns on the payload subcontract. The quality and engineering problems are the result of

the subcontractor's lack of experience and systems engineering procedures that are not clearly written. In response, the prime contractor reviewed the subcontractor's quality program. During this time, there was a 2-month stoppage of work at the subcontractor facility and the majority of the subcontractor's effort was concentrated on resolving failures noted during assembly, integration, and testing of the satellite components. When work restarted at the facility, the subcontractor continued to encounter difficulties in assembling the sensors and preparing the appropriate test equipment needed for sensor-level testing. Based on these factors and the significant remaining tasks, the prime contractor stepped up its presence at the subcontractor's facility. In addition, the subcontractor added technicians who have more experience working with space hardware and brought in systems engineers to work with the technicians.

Despite these issues, the program office still expects the prime contractor to deliver and launch the satellites earlier than the contract date of July 2007.

### **Agency Comments**

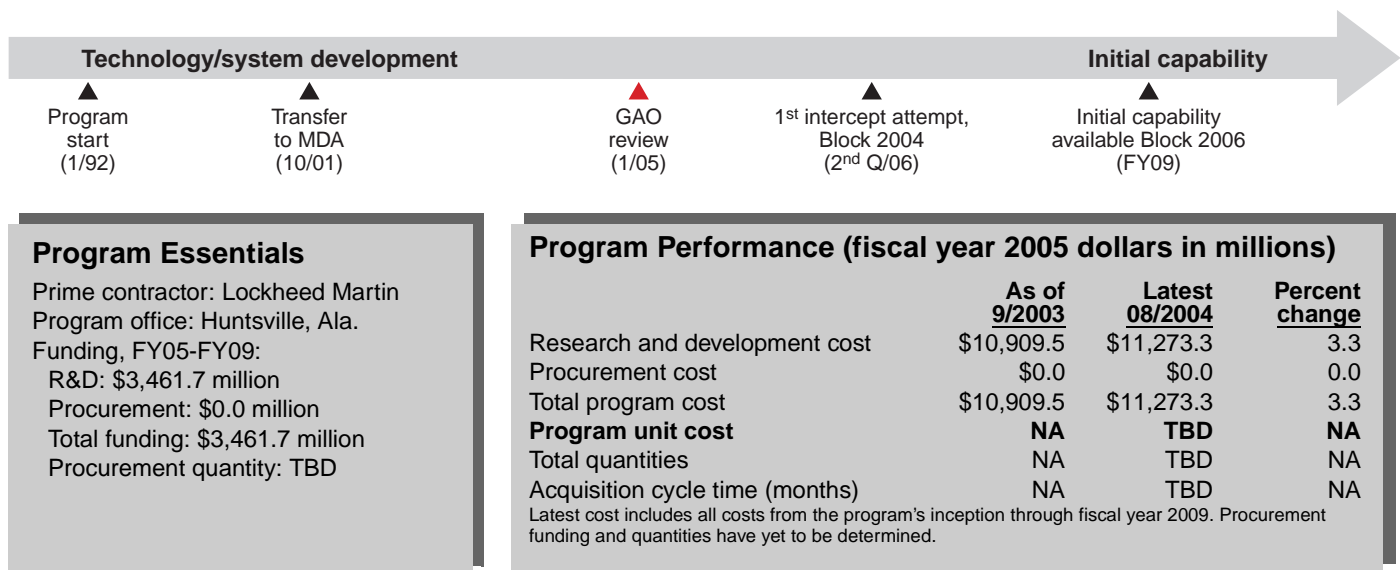
In commenting on a draft of this assessment, MDA generally concurred with our assessment and provided technical comments, which were incorporated where appropriate.

## Terminal High Altitude Area Defense (THAAD)

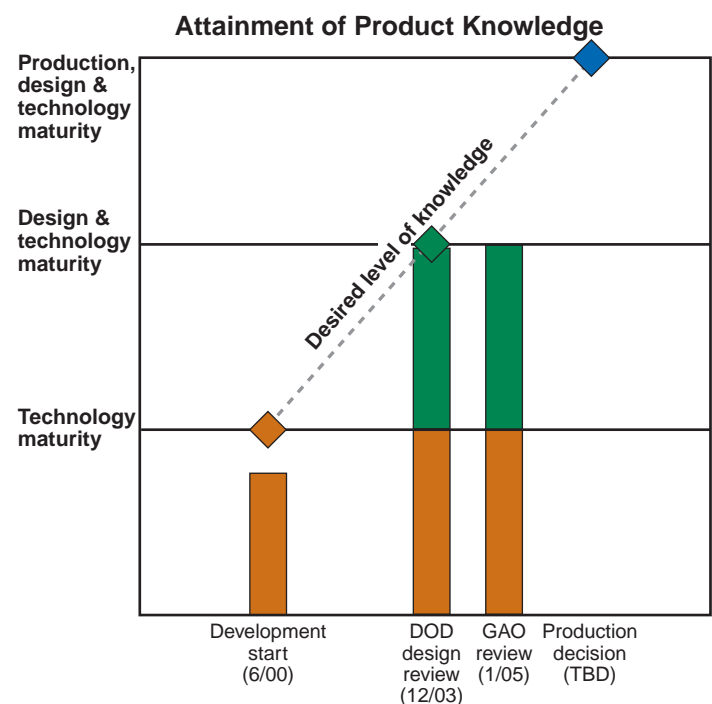
MDA's THAAD element is being developed in incremental, capability-based blocks to provide a ground-based missile defense system able to defend against short-and medium-range ballistic missile attacks. THAAD will include missiles, a launcher, an X-band radar, and a command and control/battle management system. We assessed the design for the Block 2006 initial capability of one fire unit that MDA plans to hand off to the Army for concurrent operation and testing in fiscal year 2009.



Source: THAAD Project Office.



Program officials assess THAAD's technologies as mature and its design as generally stable. The technology assessments, however, are sometimes based on tests of earlier component designs. The design of Block 2006, which is expected to provide a limited operational capability, is a further maturation of THAAD's Block 2004 design. While 91 percent of the Block 2004 engineering drawings have been released, the total number of drawings for the 2006 capability could increase if problems are identified in flight tests scheduled to begin early next year.



## **THAAD Program**

### **Technology Maturity**

Program officials assess all of THAAD's critical technologies as mature. These technologies are included in four major components: the command, control, and battle management component; the interceptor; the launcher; and the radar.

After experiencing early test failures, program officials made changes in the execution of the THAAD program that allowed it to make progress in maturing critical technologies. Officials placed more emphasis on risk reduction efforts, including adopting technology readiness levels to assess technological maturity.

### **Design Stability**

THAAD's basic design is nearing completion, with approximately 91 percent of the expected engineering drawings released for the basic design that is expected to provide the initial capability. However, the THAAD Program Office reported a decrease in the percentage of drawings released this year (91 percent) compared to the percentage reported last year (100 percent). In 2003, the program reported that it had released all of the expected 9,852 drawings. However, as the design matured, the program office recognized that 11,221 engineering drawings would be required and that it had released only 10,221 of those drawings. The number of drawings increased as information was gained from testing, the design of experimental items was completed, existing drawings were revised, and as new subcomponents were needed to replace obsolete ones. The program office successfully conducted a design review in December 2003. However, if problems are identified during flight testing, the number of drawings may increase as the design matures during Block 2006.

### **Production Maturity**

We did not assess THAAD's production maturity because MDA does not know when it will transition THAAD to the Army for production. The one fire unit that will be handed off to the Army in 2009 for limited operational use is considered to be primarily a test asset. Prior to a production decision, the program office plans to assess production maturity using Baseline Manufacturing Readiness Risk

Assessments and Block Process Verification Reviews for assurance of the contractor's readiness to proceed with repeatable processes and quality.

### **Other Program Issues**

Although the THAAD program has implemented many procedures to reduce program risk, it continues to encounter some problems. For example, the program experienced a major workmanship problem in a shelter subsystem within the command, control, and battle management component. In addition, an explosion at the Pratt & Whitney propellant mix facility is causing the program to seek an alternate source. The program office's risk assessment states "source replacements have the potential for delaying booster delivery during the flight test program and into production."

MDA officials are examining whether one THAAD component can be deployed early. Officials are assessing whether a THAAD-like radar can serve as a forward-deployed radar for the Ballistic Missile Defense System. Development, customization, and testing of the radar under another MDA program have begun in an effort to provide this capability within the next 2 years.

### **Agency Comments**

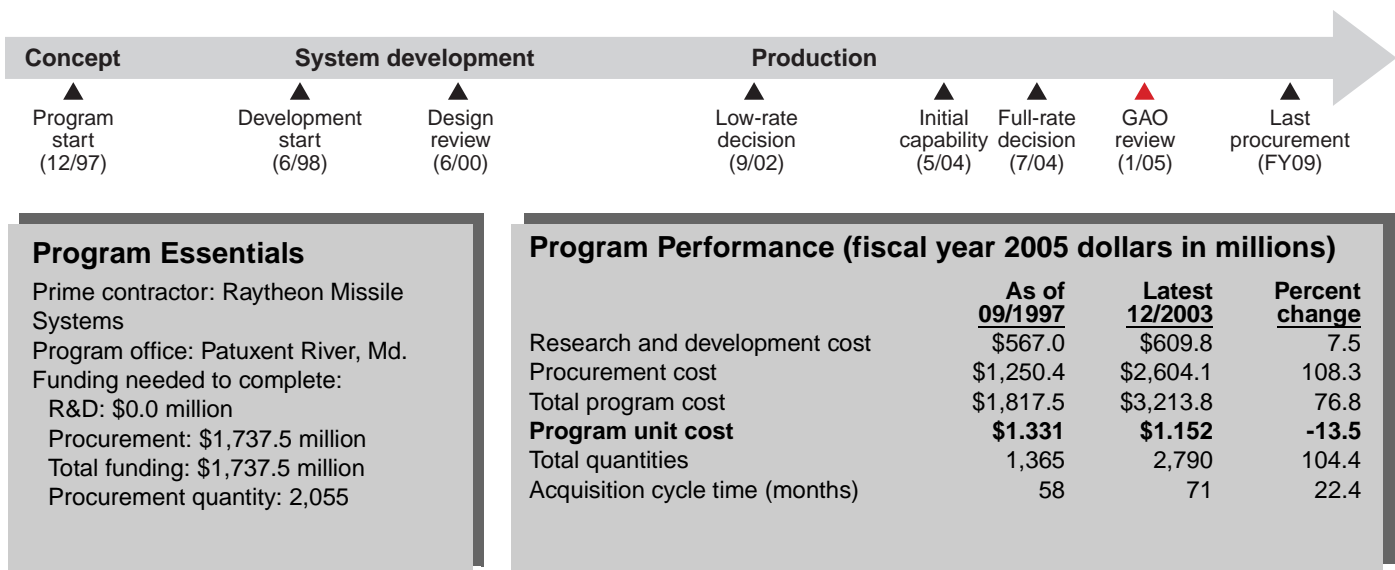
In commenting on a draft of this report, MDA provided technical comments, which were incorporated as appropriate.

## Tactical Tomahawk Missile

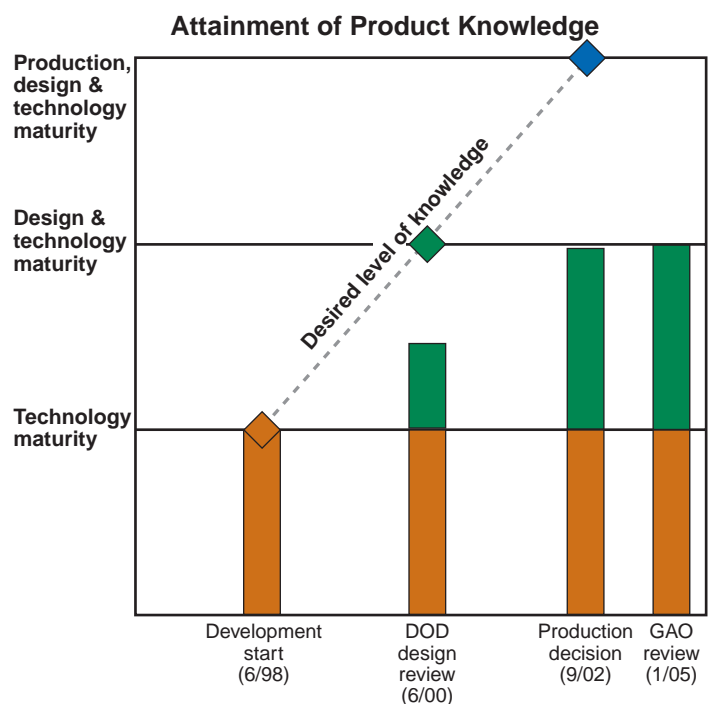
The Navy's Tactical Tomahawk Block IV will allow ships and submarines to attack land targets. Program officials say it incorporates new subsystem features like an improved antijamming global positioning system, in-flight retargeting, and transmission of imagery prior to impact. They also said it will have greater reliability and its average per unit cost will be \$729,000 versus the \$1.4 million of its predecessor. The Block IV includes the missile, the weapon control system, and the mission planning system. We assessed only the missile.



Source: Tomahawk Program Office (PMA-280).



The Tactical Tomahawk Block IV program entered low-rate production and awarded its full-rate production contract without the knowledge needed to ensure its production processes were in control but with mature technology and design knowledge. The program received its first low-rate production missile in May 2004. Other missiles such as those used in operational testing, while production representative, were mostly put together one at a time, so their manufacture was insufficient for collecting statistical data necessary for process control. Officials did not expect that the program would produce and test sufficient missile quantities to have the necessary knowledge about its production processes until sometime during March or April of 2005. Delivery of its first full-rate production missiles in January 2006 depends on completing substantial testing/verification.



## Tomahawk Program

### Technology Maturity

We did not assess the readiness level of the key technologies for the Tactical Tomahawk Block IV because its subsystems were derivative from other programs or upgrades to preexisting subsystems. Therefore, according to program officials, the critical technologies for the missile's key subsystems like the antijamming global positioning system, the digital scene matching area correlator, and the cruise engine were already mature.

### Design Stability

The design of the Tactical Tomahawk missile is complete. At the design review in June 2000, about 47 percent of the drawings had been released to manufacturing. By the end of technical evaluation in October 2003, 100 percent of the drawings had been released. Technical evaluation was successfully completed, and the program entered operational evaluation in December 2003. Operational evaluation was completed in 2004, and the missile was judged operationally effective and suitable.

### Production Maturity

We could not assess the production maturity of the Tactical Tomahawk Block IV missile because program officials said statistical process data needed for production maturity were not available. Although the Block IV uses much existing technology to reduce costs, the technology is arranged inside the missile in a new manner. The new layout makes the production process sufficiently different enough that it requires development of new production processes and statistical controls. Officials said the program had not yet produced and tested sufficient missile quantities to attain this statistical control information. Tomahawk officials currently project the program will obtain production maturity prior to January 2006.

The Navy's Operational Test and Evaluation Force judged the missile operationally suitable and effective for combat operations but also recommended review of quality assurance processes. Prior to this recommendation, the program had engaged outside experts to conduct a quality audit. The audit team concluded the audited facilities would consistently supply material to meet the program's requisite product and process

capability requirements. The team also noted opportunities for improvement in areas like statistical process control. Officials said a follow-up Navy/Raytheon (the prime contractor) review indicated that progress had been made in all areas identified for improvement. They also said Raytheon had contracted for ongoing outside support for implementation of quality initiatives.

### Other Program Issues

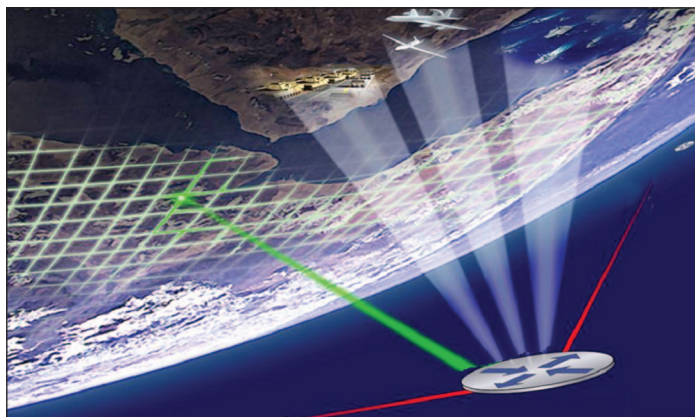
At the time of our review, a full-rate 5-year production contract had been awarded, with the multiyear feature designed to provide earliest replenishment of inventory at lowest cost. Full-rate production is planned for fiscal year 2004 through fiscal year 2008.

### Agency Comments

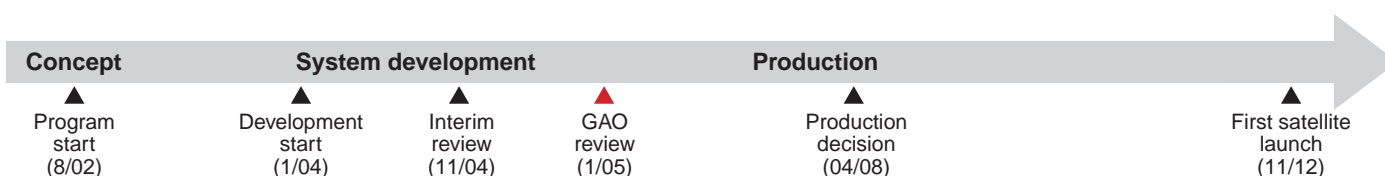
Commenting on a draft of this assessment, the Navy provided technical comments, which were incorporated where appropriate. It also noted that all Block IV production processes have been fully defined and are maturing.

## Transformational Satellite Communications System (TSAT)

The Air Force's TSAT system is designed to provide survivable, jam-resistant, global, secure, and general-purpose laser cross-links with other air and space systems, including the planned AEHF satellite system, reviewed elsewhere in this report. TSAT will serve as the cornerstone of a new DOD communications infrastructure by providing high bandwidth connectivity to the warfighter. The system consists of a constellation of five satellites, plus a sixth satellite to ensure mission availability. We assessed the six satellites.



Source: Northrop Grumman Corporation.



### Program Essentials

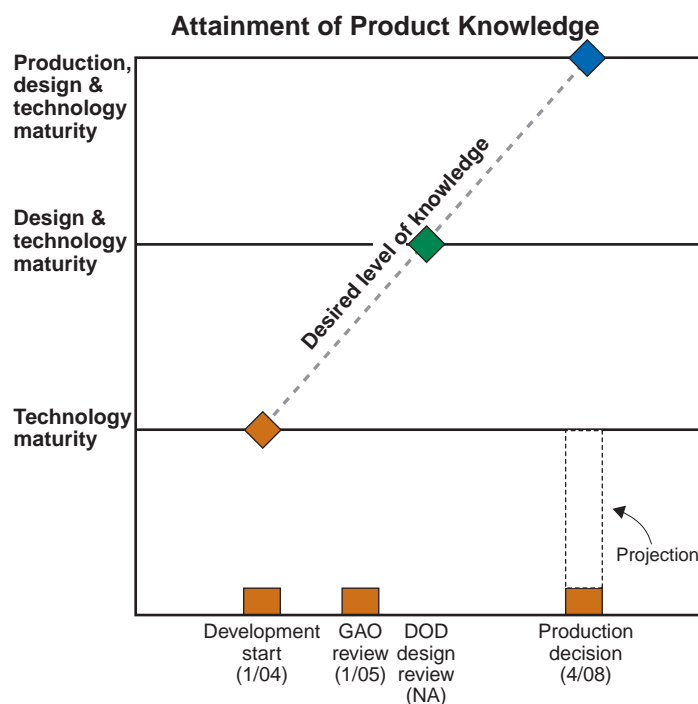
Prime contractor: Boeing, Lockheed Martin, Northrop Grumman, Raytheon, Booz Allen Hamilton  
 Program office: El Segundo, Calif.  
 Funding needed to complete:  
 R&D: \$12,012.7 million  
 Procurement: \$3,576.1 million  
 Total funding: \$15,663.7 million  
 Procurement quantity: 4

### Program Performance (fiscal year 2005 dollars in millions)

	As of 01/2004	Latest 06/2004	Percent change
Research and development cost	\$12,463.7	\$12,463.7	0.0
Procurement cost	\$3,576.1	\$3,576.1	0.0
Total program cost	\$16,114.6	\$16,114.6	0.0
<b>Program unit cost</b>	<b>\$2,685.771</b>	<b>\$2,685.771</b>	<b>0.0</b>
Total quantities	6	6	0.0
Acquisition cycle time (months)	117	122	4.3

In 2004 we reported a total quantity of 10 satellites, including 4 replenishment satellites. The approved quantity is currently 6 satellites.

TSAT entered the risk reduction and design development phase in January 2004 with only one of its seven critical technologies mature. The program expects to demonstrate technology maturity but not design stability or production maturity before awarding a contract to acquire operational satellites in 2006.



## TSAT Program

### Technology Maturity

The TSAT program is in the risk reduction and design development phase, with only one of its seven critical technologies mature. The program is being developed in two increments—six of the technologies are associated with the first increment and all seven are associated with the second increment.

Of the six technologies associated with the first increment, only one technology—the packet processing payloads—is mature. The other five—communication-on-the-move nulling antenna, dynamic bandwidth and resource allocation technologies, protected bandwidth efficient modulation waveforms, information assurance, and single access laser communications—are scheduled to reach maturity in early 2006, about 2 years after the start of development. The single access laser communications has no backup technology, and according to program officials, any delay in maturing this technology will cause the expected first satellite launch date to slip beyond 2012.

The seventh critical technology, the multiaccess laser communications, is part of the second increment. It will not reach maturity until the production decision for the last four operational satellites in 2008, about 4 years after the planned start of development.

### Other Program Issues

Unlike current communications satellites, TSAT will be equipped with laser-optical payloads for high-capacity links to other air and space platforms. AEHF will depend on the first TSAT satellite, now scheduled for launch by the end of 2012, to provide full global coverage. Because military users are concerned with the aggressive acquisition strategy, the Air Force scheduled an interim review point for November 2004 to determine whether the technology development had progressed sufficiently to meet the required launch date and decided to continue with both AEHF and TSAT development. A second interim review point is scheduled for November 2005, at which point the Air Force must decide on alternatives, one of which is to buy an additional AEHF satellite. Air Force officials are in

the process of defining the evaluation criteria they intend to use to assess TSAT's progress or identify alternatives.

TSAT is currently being rebaselined as a result of a congressional reduction totaling \$300 million in research and development funding for fiscal year 2005. The defense authorization conference report indicated that funding was reduced because of continuing concerns related to the risk of the current acquisition approach.

### Agency Comments

In commenting on a draft of this assessment, the Air Force stated that, based on commercial and DOD best practices, all TSAT technologies meet, or exceed, the level of maturity appropriate for the current risk reduction and design development phase and that this phase provides the data (technology readiness and design maturity) necessary for a production contract award. It also commented that all key technologies are on schedule to achieve maturity 10 months prior to Preliminary Design Review and that, to further reduce risk, TSAT has backup technologies in all areas in the event that a technology is not ready. It noted that the backup technologies would still provide a large increase in warfighter capability and allow for technologies to be used on later TSAT satellites. It also noted that to be effective, risk reduction and preliminary design must be done concurrently and iteratively. If not, the program risks maturing technology that does not support the system design, resulting in scrap and rework. It believes that this strategy delivers the greatest warfighter capability at minimum risk and cost.

### GAO Comments

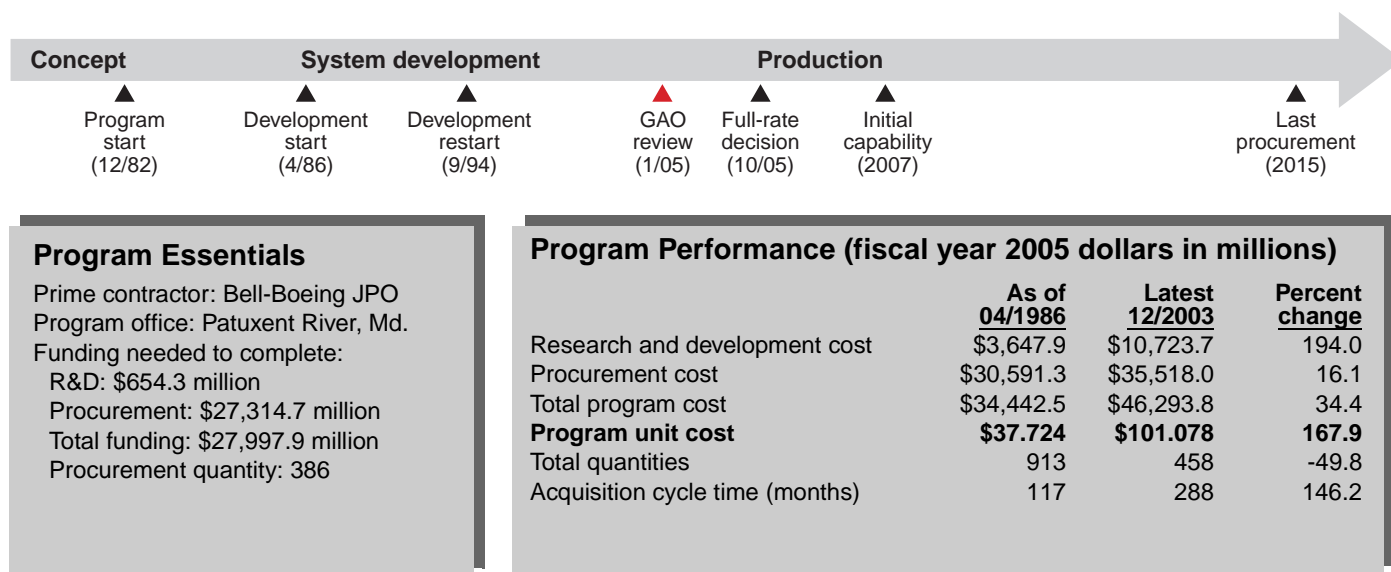
Our prior work has shown that technologies should demonstrate a high level of maturity before starting development to reduce the risk of cost, schedule, and performance problems. Although the program started development a year ago, we found that several critical technologies had demonstrated very low levels of maturity involving analytical studies and the demonstration of nonscale individual components in a laboratory environment.

## V-22 Joint Services Advanced Vertical Lift Aircraft

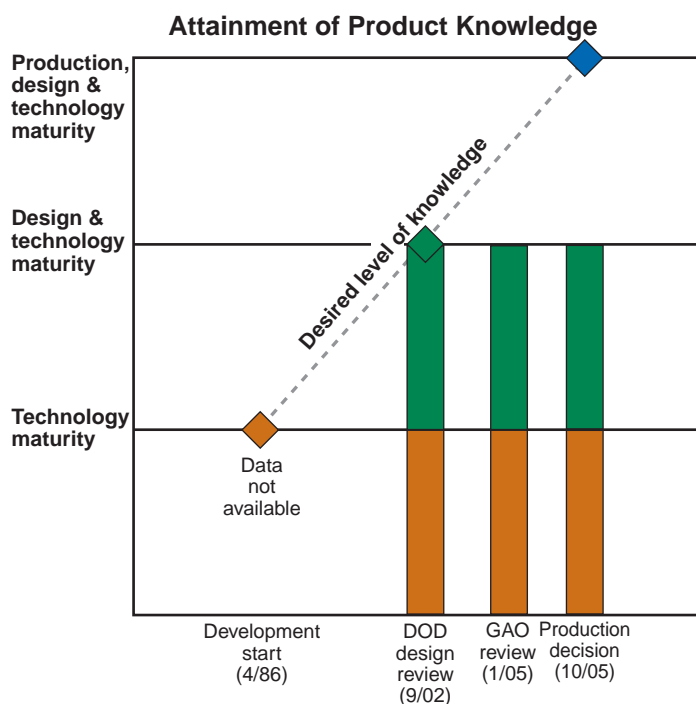
The V-22 Osprey is a tilt rotor, vertical takeoff and landing aircraft being developed by the Navy for Joint Service application. It is designed to meet the amphibious/vertical assault needs of the Marine Corps, the strike rescue needs of the Navy, and the special operations needs of the Air Force and the U.S. Special Operations Command. The MV-22 version will replace the CH-46E and CH-53D helicopters of the Marine Corps. We assessed the MV-22 Block A, which has been undergoing changes to make it safe and operational.



Source: U.S. Navy.



MV-22 Block A technologies are mature and the design is considered stable. Problems identified during recent tests are expected to be resolved prior to the next operational test, according to program officials. Some redesign efforts have been identified as candidates for preplanned product improvements. Parts issues and delayed reporting of test results could delay the operational performance certification needed to increase production in fiscal year 2006. Decisions on whether to lift current flight restrictions, prior to the completion of operational evaluation, will be made on a case-by-case basis. Recent tests found interoperability and human factors as high-risk issues that may impact this evaluation. Also, the contractors were asked to propose cost reduction initiatives targeted at reducing aircraft unit cost to \$58 million by fiscal year 2010.



## V-22 Program

### Technology Maturity

Although we did not assess the MV-22's technology maturity, the program office states that based on DOD criteria, the Block A technologies are mature. During recently completed limited operational tests, technology maturity was assessed in a range of environmental conditions. Program officials state that problems were identified and corrective plans implemented to insure a successful operational test and evaluation assessment.

### Design Stability

Design for Block A is considered stable. However, additional changes to later blocks of the aircraft have been identified. These changes include redesign of the forward cabin; redesign of the rear cabin seating, which is considered inadequate for combat equipped troops; redesign of an extendable tube for fuel jettison operations; and enhancements to improve wheel brake control and effectiveness.

### Production Maturity

Process management is becoming more robust at the final assembly site on each major fixture assembly using Six Sigma. Program officials point to the delivery of aircraft as an indication of manufacturing maturity.

An independent review assessed a V-22 parts problem at one of the contractors' plants that could affect its ability to support full-rate production and concluded that in the near term they believe the current parts shortage could be addressed with heroics. However, the team and program officials are concerned with the institutionalization of long-term process improvements and recommended development of a plan that addresses both short-term part shortages and implementation of a full-rate production plan.

The Navy plans to increase annual production of the aircraft starting in fiscal year 2006, provided the Secretary of Defense certifies to Congress that the program successfully completed operational testing by demonstrating several capabilities related to V-22 safety, effectiveness, maintainability, and reliability (Section 123, Pub. Law 107-107, Dec. 28, 2001) through operational test. The certification would allow the program to increase annual production above the current minimum sustaining rate. Program

officials are concerned that the certification cannot be done before completion of the fiscal year 2006 budget process and, as a result, the request to increase production may not be granted.

### Other Program Issues

The V-22 is currently being tested with operating limits, such as defensive combat maneuver capability. Decisions on whether to relax or remove specific restrictions will be made on a case-by-case basis prior to the completion of operational evaluation in June 2005. The decisions on these restrictions will impact the result of the upcoming operational assessment. A recently completed limited assessment concluded that out of 16 critical operational issues, 2 were at high risk and 6 at medium risk of not achieving a satisfactory resolution during upcoming operational testing. The high-risk issues are interoperability and human factors. The medium-risk issues are reliability, availability, logistics support, compatibility, documentation, and diagnostics. Recently, the program requested that the contractor submit a proposal for combining cost reduction initiatives to reduce the aircraft unit price to a target price of \$58 million in fiscal year 2010.

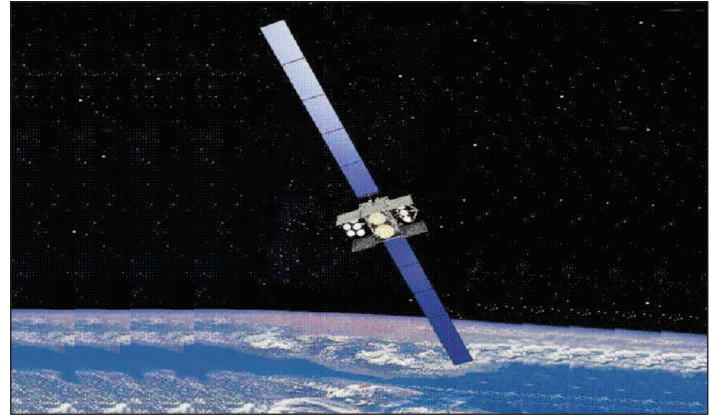
### Agency Comments

In commenting on a draft of this assessment, the Navy stated that the V-22 Joint Program Office continues to execute a disciplined, event-driven test and program schedule. It noted that since returning to flight in 2003, the V-22 has flown over 4,000 hours, both in development and operational tests. It also stated that the Block A V-22 has demonstrated reliability and maintainability on par with fleet aircraft and that multiship sorties and operations have been demonstrated for nearly all missions. It further commented that the range and speed capability of the V-22 has spawned new tactics and realized logistics efficiencies that will reduce time, resources and save lives.

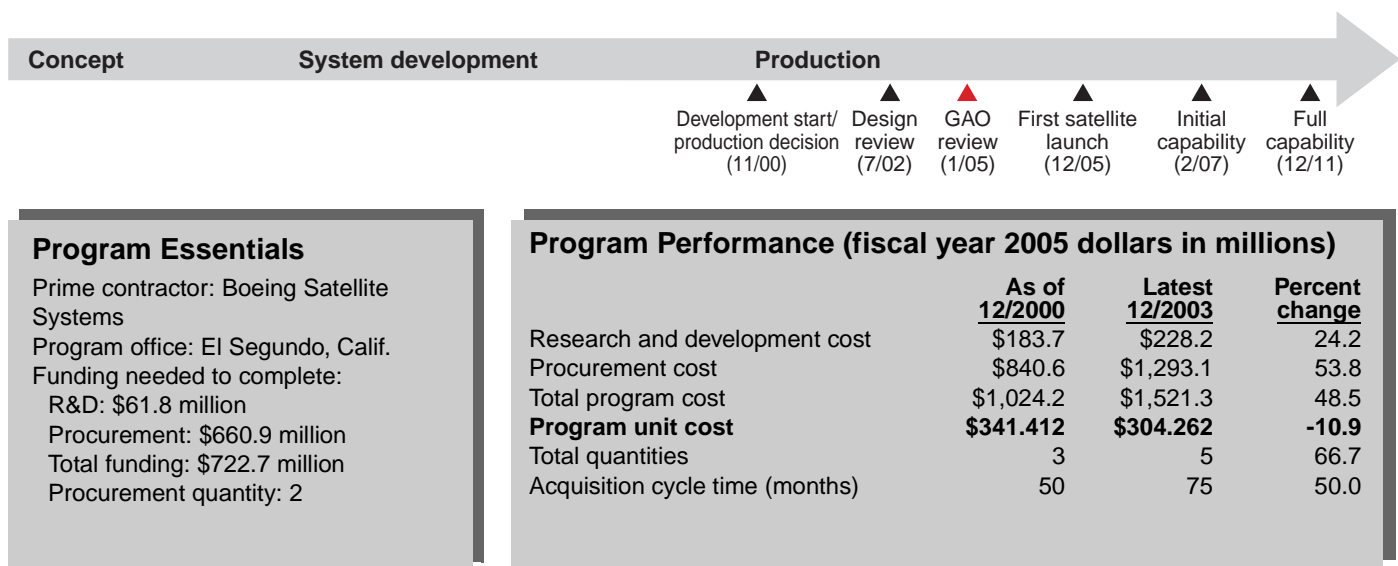
The Navy also stated that it remains committed to fielding a V-22 weapon system when it is tested and ready and noted that a talented team of government and industry professionals champions the transformational capability that the V-22 brings and is committed to its success. It further stated that the test and training programs will continue to ensure operators and maintainers are ready and capable from day one to ensure the warfighter has the best equipment with the best information.

## Wideband Gapfiller Satellites (WGS)

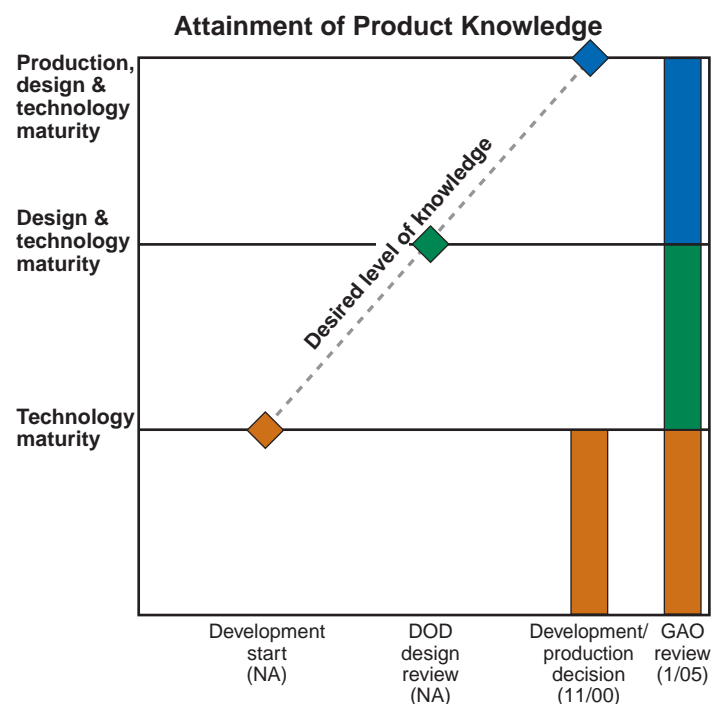
WGS is a joint Air Force and Army program intended to provide essential communications services to U.S. warfighters, allies, and coalition partners during all levels of conflict short of nuclear war. It is the next generation wideband component in DOD's future Military Satellite Communications architecture and is composed of the following principal segments: space segment (satellites), terminal segment (users), and control segment (operators). We assessed the space segment.



Source: WGS Program Office.



The WGS program's technology, design, and production are now mature. Manufacturing problems did contribute to a delay in the launch of the first WGS satellite by almost 2 years. The program office is increasing its oversight of the contractor to help rectify these issues and believes the problems have been resolved. A decision to procure the fourth and fifth satellites is expected to add millions of dollars to the program's cost, but the program office will not know the cost of these satellites until it receives a proposal from the contractor.



## **WGS Program**

### **Technology Maturity**

WGS has two technologies that are vital to program success: the digital channelizer and the phased array antenna. According to program officials, both technologies were mature when the program entered production in November 2000.

### **Design Stability**

The WGS design is essentially complete, as the program office has released over 97 percent of the expected drawings to manufacturing. Last year we reported that the contractor had problems integrating the antenna into the satellite because experience the contractor expected to gain on commercial satellite orders did not materialize. The integration problems have since been resolved, and testing of the antenna engineering models demonstrated that the design worked as required.

### **Production Maturity**

Due to the commercial nature of the WGS acquisition contract, the program office does not have access to production process control data. Despite not being able to access these data to determine production maturity, unit level manufacturing for WGS is essentially complete, as all units have been manufactured and delivered for the first satellite. The contractor continues to experience difficulties in manufacturing one of the components of the phased array antenna, making the antenna production the top risk to the program. Approximately 254 of these antenna components were being built when thin cracks in the copper striplines were noticed during inspection. An early analysis showed that poor handling procedures of inexperienced personnel contributed to the cracks, and a screening test revealed that inconsistencies in the thickness of the copper trace used to build the striplines were also to blame. The contractor replaced all the flawed striplines with properly manufactured parts and implemented additional process controls. In resolving these production issues, program officials stated that they inspected the manufacturing facilities, reviewed test plans and procedures, started screening parts, and now hold monthly program reviews with the contractor. Manufacturing problems with the phased array antenna contributed to delaying the launch of the first WGS satellite by almost 2 years. As a result of

the delay, the Air Force revised its acquisition strategy program baseline, which was approved in February 2004.

### **Other Program Issues**

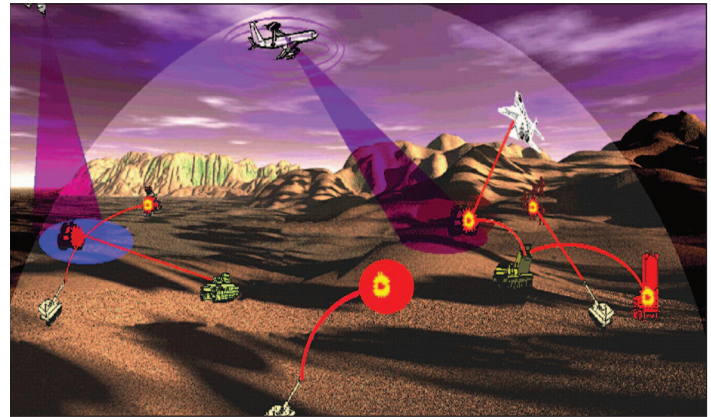
In December 2002, DOD directed the addition of WGS satellites four and five, with launch dates of fiscal years 2009 and 2010, respectively. Therefore, the current contract options must be extended and renegotiated to cover the cost of the likely 2- to 3-year production gap between satellites three and four. The cost estimate for the additional satellites has grown because of a greater than anticipated effect of parts obsolescence and loss of manufacturing knowledge to be gained during the production of the first three satellites. In addition, the production costs of the first three satellites have been higher than expected. The procurement of satellites four and five is expected to add millions of dollars to the cost of the WGS program, but the exact amount will not be known until the program office receives a proposal from the contractor. Negotiation for the two satellites is to begin in the second half of fiscal year 2006.

### **Agency Comments**

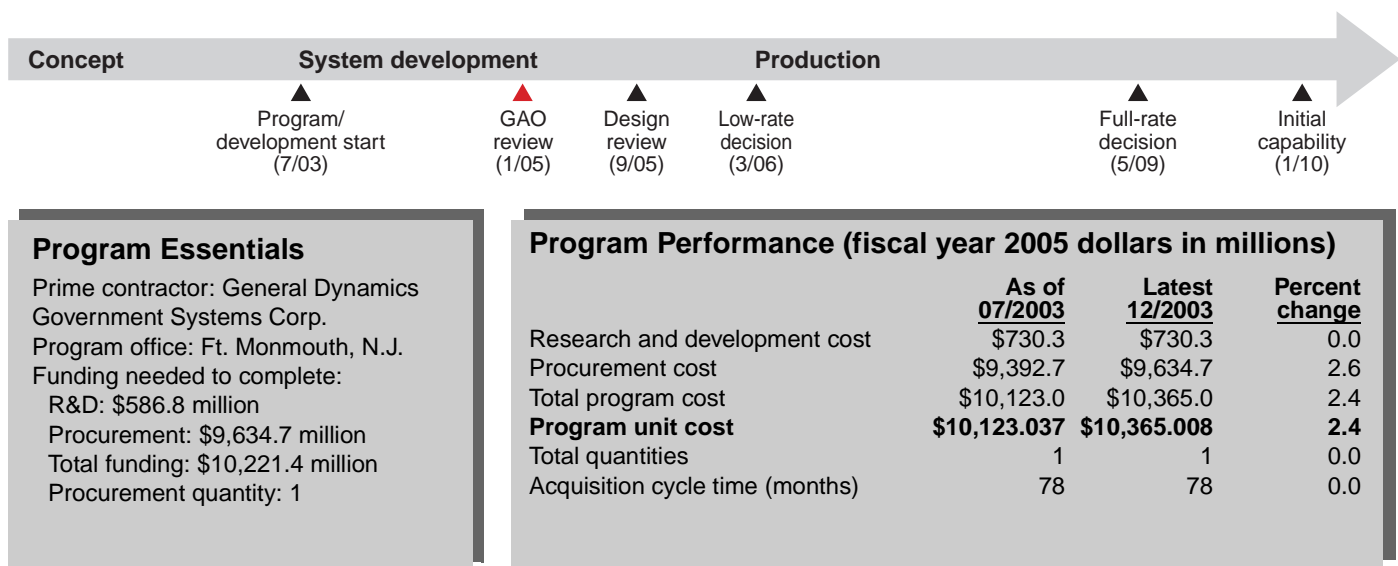
In commenting on a draft of this assessment, the program office stated that even though manufacturing process information is unavailable, it believes the production knowledge of WGS is mature based upon similarities to the contractor's commercial communications satellites. In addition, the delays experienced in the delivery of the first satellite were primarily due to inadequate adherence to manufacturing and quality assurance standards at subcontractor facilities rather than production knowledge immaturity.

## Warfighter Information Network-Tactical (WIN-T)

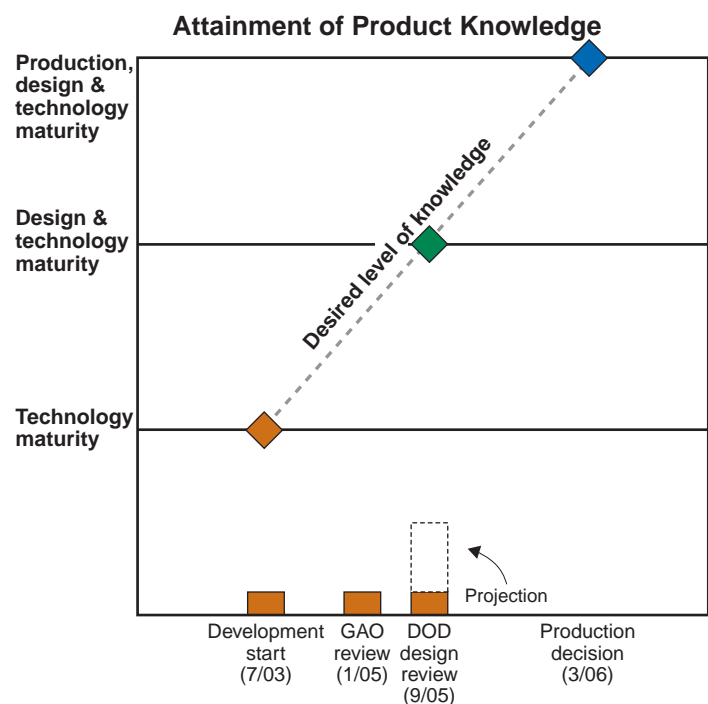
WIN-T is the Army's high-speed and high-capacity backbone communications network. It is to provide reliable, secure, and seamless video, data, imagery, and voice services, allowing users to communicate simultaneously at various levels of security. The network is to have the ability to be initialized and modified based upon unit task organization. It is to connect Army units with higher levels of command and provide Army's tactical portion of the Global Information Grid. WIN-T is being fielded in blocks. We assessed the first block.



Source: PM WIN-T.



WIN-T entered system development with 3 of its 12 critical technologies close to full maturity. None of the technologies will be fully mature at the time production begins in March 2006. Eight have backup technologies available, but only three of these are fully mature, and use of backup technologies would degrade system overall robustness and capabilities. Due to significant interdependencies among critical technologies, and the fact that some determine network functionality, it may not be possible to demonstrate that those technologies are fully mature until after production begins. Design stability could not be assessed because the program office does not track the number of releasable drawings. WIN-T is primarily an information technology system integration effort rather than a manufacturing effort.



## **WIN-T Program**

### **Technology Maturity**

WIN-T entered system development with 3 of its 12 critical technologies close to reaching full maturity. While program officials do not expect these technologies to reach full maturity until the network is built and can be demonstrated in an operational environment, they do expect the technologies to have been demonstrated in a simulated operational environment by the time the critical design review is held in September 2005. An independent Army technology readiness assessment determined that WIN-T would enter system development prior to full definition of the first block's design and specific technology-based components, systems, or subsystems. WIN-T will include technologies such as mobile and static communications nodes, network operations and support centers, transmission relays, joint gateway nodes, points of presence for future force and command elements, vehicular wireless packages, airborne wireless communication packages, and personal communications devices.

### **Design Stability**

Design stability could not be assessed because the program office does not plan to track the number of releasable drawings as a design metric. According to the program, WIN-T is not a manufacturing effort, but primarily an information technology system integration effort. Consequently, the government does not obtain releasable design drawings for many of WIN-T's components, particularly commercial components. The WIN-T design will evolve using performance-based specifications and open systems design, and it is to conform to DOD's Joint Technical Architecture.

### **Other Program Issues**

Among other issues, the program will need to pay close attention to the interdependent nature of the WIN-T, FCS, and JTRS programs, the interrelationship between WIN-T and FCS and Global Information Grid requirements, the scalability of WIN-T, the challenge of linking all the nodes and networks of the Army's system-of-systems, and the coordination of unmanned relay programs with FCS. The program will also have to track external factors that will impact WIN-T such as the DOD Net-Centric Data Strategy. WIN-T deployment will be essential for FCS deployment

and as each system evolves, integration demonstrations will need to be performed to ensure WIN-T and FCS interoperability.

In addition, a major revision to the WIN-T acquisition strategy is underway. WIN-T was originally envisioned to support the Army's Future Force. However, the global war on terrorism and the lessons learned from recent military operations have shifted the Army's focus toward providing WIN-T capabilities sooner. To accomplish this, DOD, in September, approved a decision to combine the competing contractor teams for WIN-T's system design and development. The two originally competing contractors are now teaming to establish a single architecture for WIN-T that, according to the revised acquisition strategy, will leverage each contractor's proposed architecture to provide the Army with a superior technical solution for WIN-T. Establishing the single WIN-T architecture a year earlier than originally planned is expected to allow other Army programs to begin to follow that architecture for near-term force procurements and build on that architecture for the Future Force.

### **Agency Comments**

In commenting on a draft of this assessment, the Army noted that, as a result of merging the two competing prime contractors under a new acquisition strategy, the "best of breed" critical technologies will be used in the updated WIN-T architecture. This new strategy is also expected to increase the range of available technical products and developing technologies, thereby lowering the risk of maturing critical technologies for production and fielding. The Army also provided technical comments, which were incorporated where appropriate.

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## Agency Comments and Our Evaluation

DOD did not provide general comments on a draft of this report, but it did provide technical comments. These comments, along with agency comments received on the individual assessments, were included as appropriate. (See app. I for a copy of DOD's response.).

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## Scope of Our Review

For the 54 programs, each assessment provides the historical and current program status and offers the opportunity to take early corrective action when a program's projected attainment of knowledge diverges significantly from the best practices. The assessments also identify programs that are employing practices worthy of emulation by other programs. If a program is attaining the desired levels of knowledge, it has less risk—but not zero risk—of future problems. Likewise, if a program shows a gap between demonstrated knowledge and best practices, it indicates an increased risk—not a guarantee—of future problems. The real value of the assessments is recognizing gaps early, which provides opportunities for constructive intervention—such as adjustments to schedule, trade-offs in requirements, and additional funding—before cost and schedule consequences mount.

We selected programs for the assessments based on several factors, including (1) high dollar value, (2) stage in acquisition, and (3) congressional interest. The majority of the 54 programs covered in this report are considered major defense acquisition programs by DOD. A program is defined as major if its estimated research and development costs exceed \$365 million or its procurement exceeds \$2.19 billion in fiscal year 2000 constant dollars. (See app. II for details of the scope and methodology.)

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We are sending copies of this report to interested congressional committees; the Secretary of Defense; the Secretaries of the Army, Navy, and Air Force; and the Director, Office of Management and Budget. We will also make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at <http://www.gao.gov>.

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If you have any questions on this report, please contact me at (202) 512-4841 or Paul Francis at (202) 512-4841. Major contributors to this report are listed in appendix IV.

A handwritten signature in black ink, reading "Katherine V. Schinasi". The signature is fluid and cursive, with the first name "Katherine" and last name "Schinasi" being more prominent than the middle initial "V".

Katherine V. Schinasi  
Managing Director  
Acquisition and Sourcing Management

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*List of Congressional Committees*

The Honorable John W. Warner  
Chairman

The Honorable Carl Levin  
Ranking Minority Member  
Committee on Armed Services  
United States Senate

The Honorable Ted Stevens  
Chairman

The Honorable Daniel K. Inouye  
Ranking Minority Member  
Subcommittee on Defense  
Committee on Appropriations  
United States Senate

The Honorable Duncan Hunter  
Chairman

The Honorable Ike Skelton  
Ranking Minority Member  
Committee on Armed Services  
House of Representatives

The Honorable C. W. Bill Young  
Chairman

The Honorable John P. Murtha  
Ranking Minority Member  
Subcommittee on Defense  
Committee on Appropriations  
House of Representatives

# Comments from the Department of Defense



ACQUISITION  
TECHNOLOGY  
AND LOGISTICS

OFFICE OF THE UNDER SECRETARY OF DEFENSE  
3000 DEFENSE PENTAGON  
WASHINGTON, DC 20301-3000

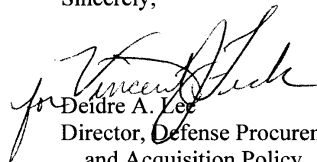
MAR 07 2005

Mr. Paul Francis  
Director, Acquisition and Sourcing Management  
U.S. Government Accountability Office  
441 G Street, N.W.  
Washington, D.C. 20548

Dear Mr. Francis:

This is the Department of Defense response to the GAO draft report, *Defense Acquisitions: Assessments of Major Weapon Programs*, dated February 11, 2005 (GAO Code 120350/GAO-05-301). We have enclosed technical comments to ensure accuracy. These comments should be reflected in the final report and in the individual program summaries. My point of contact is Mr. Skip Hawthorne, (703) 692-9556, or e-mail: skip.hawthorne@osd.mil.

Sincerely,

  
Deidre A. Lee  
Director, Defense Procurement  
and Acquisition Policy

Enclosure:  
As stated



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# Scope and Methodology

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In conducting our work, we evaluated performance and risk data from each of the programs included in this report. We summarized our assessments of each individual program in two components—a system profile and a product knowledge assessment. We did not validate the data provided by the Department of Defense (DOD). However, we took several steps to address data quality. Specifically, we reviewed the data and performed various quality checks, which revealed some discrepancies in the data. We discussed the underlying data and these discrepancies with program officials and adjusted the data accordingly. We determined that the data provided by DOD were sufficiently reliable for our engagement purposes, after reviewing DOD’s management controls for assessing data reliability.

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## Macro Analysis

Data for major defense acquisition program research, development, test, and evaluation (RDT&E) and procurement funding in figure 1 were obtained from DOD’s selected acquisition reports or from data obtained directly from the program offices and then aggregated across programs between fiscal year 1998 and fiscal year 2009. Data used to assess the fiscal year 2005 RDT&E and procurement funding plan were drawn from the 2003 selected acquisition reports or obtained directly from the program office. For the Missile Defense Agency (MDA) programs for which a baseline was not available, we used the latest available cost information.

To assess the total cost, schedule, and quantity changes of the programs included in our assessment, it was necessary to identify those programs with all of the requisite data available. Of the 54 programs in our assessment, 26 programs constituted the common set of programs where data were available for cost, schedule, and quantity at the first full estimate, generally milestone B, and the latest estimate. Data utilized in this analysis were drawn from information contained in selected acquisition reports or data provided by program offices as of January 14, 2005. We summed the costs associated with RDT&E and total costs consisting of research, development testing and evaluation, procurement, military construction, and acquisition operation and maintenance. The data were also used for a comparison between the 2004 assessment period and the 2005 assessment period. The schedule assessment is based on the change in the average acquisition cycle time, defined as the number of months between program start and the achievement of initial operational capability or an equivalent fielding date.

The weighted calculations of acquisition cycle time and program acquisition unit cost for the common set of programs were derived by

taking the total cost estimate for each of the 26 programs and dividing it by the aggregate total cost of all 26 programs in the common set. The resulting quotient for each program was then multiplied by the simple percentage change in program acquisition unit costs to obtain the weighted unit cost change of each program. Next, the sum of this weighted cost change for all programs was calculated to get the weighted unit cost change for the common set as a whole. To assess the weighted-average acquisition cycle time change, we multiplied the weight calculation by the acquisition cycle time estimate for each corresponding program. A simple average was then taken to calculate the change between the first full estimate and the latest estimate, and between the 2004 assessment period and the 2005 assessment period. We believe these calculations best represent the overall progress of programs by placing them within the context of the common set's aggregate cost.

To assess the number of programs with technology maturity and design stability at each critical juncture, we identified programs that had actually proceeded through the start of development and the system design review and obtained their assessed maturity. This information was drawn from data provided by the program office as of January 14, 2005. For more information, see the product knowledge assessment section in this appendix.

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## System Profile Assessment

In the past 4 years, DOD revised its policies governing weapon system acquisitions and changed the terminology used for major acquisition events. To make DOD's acquisition terminology more consistent across the 54 program assessments, we standardized the terminology for key program events. In the individual program assessments, program start refers to the initiation of a program; DOD usually refers to program start as milestone I or milestone A, which begins the concept and technology development phase. Similarly, development start refers to the commitment to system development that coincides with either milestone II or milestone B, which begins DOD's system development and demonstration phase. The production decision generally refers to the decision to enter the production and deployment phase, typically with low-rate initial production. Initial capability refers to the initial operational capability, sometimes also called first unit equipped or required asset availability. For the MDA programs that do not follow the standard DOD acquisition model, but instead develop systems in incremental capability-based blocks, we identified the key technology development efforts that lead to an initial capability for the block assessed.

The information presented on the funding needed to complete from fiscal 2005 through completion, unless otherwise noted, draws on information from selected acquisition reports or on data from the program office. In some instances the data were not yet available, and we annotate this by the term “to be determined” (TBD), or not applicable, annotated (NA). The “Latest” program costs used in cost comparisons are the latest estimates provided by the individual programs. The quantities listed only refer to procurement quantities. Satellite programs, in particular, produce a large percentage of their total operational units as development quantities, which are not included in the quantity figure.

To assess the cost, schedule, and quantity changes of each program, we reviewed DOD’s selected acquisition reports or obtained data directly from the program offices. In general, we compared the latest available selected acquisition report information with a baseline for each program. For systems that have started system development—those that are beyond milestone II or B—we compared the latest available selected acquisition report to the development estimate from the first selected acquisition report issued after the program was approved to enter development. For systems that have not yet started system development, we compared the latest available data to the planning estimate issued after milestone I or A. For systems not included in selected acquisition reports, we attempted to obtain comparable baseline and current data from the individual program offices. For MDA systems for which a baseline was not available we compared the latest available cost information to the amount reported last year.

All cost information is presented in base year 2005 dollars, unless otherwise noted, using Office of the Secretary of Defense approved deflators to eliminate the effects of inflation. We have depicted only the programs’ main elements of acquisition cost—research and development and procurement; however, the total program costs also include military construction and acquisition operation and maintenance costs. Because of rounding and these additional costs, in some situations the total cost may not match the exact sum of the research and development and procurement costs. The program unit costs are calculated by dividing the total program cost by the total quantities planned. These costs are often referred to as program acquisition unit costs. In some instances, the data were not applicable, and we annotate this by using the term “NA.” In other instances, the current absence of data on procurement funding and quantities precludes calculation of a meaningful program acquisition unit cost and we annotate this by using the term “TBD.” The quantities listed

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refer to total quantities, including both procurement and development quantities.

The schedule assessment is based on acquisition cycle time, defined as the number of months between the program start, usually milestone I or A, and the achievement of initial operational capability or an equivalent fielding date. In some instances, the data were not yet available, and we annotate this by using the term TBD, or was classified.

The intent of these comparisons is to provide an aggregate or overall picture of a program's history. These assessments represent the sum total of the federal government's actions on a program, not just those of the program manager and the contractor. DOD does a number of detailed analyses of changes that attempt to link specific changes with triggering events or causes. Our analysis does not attempt to make such detailed distinctions.

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## Product Knowledge Assessment

To assess the product development knowledge of each program at key points in development, we submitted a data collection instrument to each program office. The results are graphically depicted in each 2-page assessment. We also reviewed pertinent program documentation, such as the operational requirements document, the acquisition program baseline, test reports, and major program reviews.

To assess technology maturity, we asked program officials to apply a tool, referred to as technology readiness levels, for our analysis. The National Aeronautics and Space Administration originally developed technology readiness levels, and the Army and Air Force Science and Technology research organizations use them to determine when technologies are ready to be handed off from science and technology managers to product developers. Technology readiness levels are measured on a scale of one to nine, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. (See appendix III for the definitions of technology readiness levels.) Our best practices work has shown that a technology readiness level of 7—demonstration of a technology in an operational environment—is the level of technology maturity that constitutes a low risk for starting a product development program. In our assessment, the technologies that have reached technology readiness level 7, a prototype demonstrated in an operational environment, are considered mature and those that have reached technology readiness level 6, a prototype demonstrated in a

relevant environment, are assessed as attaining 50 percent of the desired level of knowledge. Satellite technologies that have achieved technology readiness level 6 are assessed as fully mature due to the difficulty of demonstrating maturity in an operational environment—space.

In most cases, we did not validate the program offices' selection of critical technologies or the determination of the demonstrated level of maturity. We sought to clarify the technology readiness levels in those cases where information existed that raised concerns. If we were to conduct a detailed review, we might adjust the critical technologies assessed, the readiness level demonstrated, or both. It was not always possible to reconstruct the technological maturity of a weapon system at key decision points after the passage of many years.

To assess design stability, we asked program officials to provide the percentage of engineering drawings completed or projected for completion by the design review, the production decision, and as of our current assessment. In most cases, we did not verify or validate the percentage of engineering drawings provided by the program office. We sought to clarify the percentage of drawings completed in those cases where information existed that raised concerns. Completed engineering drawings were defined as the number of drawings released or deemed releasable to manufacturing that can be considered the "build to" drawings.

To assess production maturity, we asked program officials to identify the number of critical manufacturing processes and, where available, to quantify the extent of statistical control achieved for those processes. In most cases, we did not verify or validate this information provided by the program office. We sought to clarify the number of critical manufacturing processes and percentage of statistical process control where information existed that raised concerns. We used a standard called the Process Capability Index, which is a process performance measurement that quantifies how closely a process is running to its specification limits. The index can be translated into an expected product defect rate, and we have found it to be a best practice. We sought other data, such as scrap and rework trends, in those cases where quantifiable statistical control data were unavailable.

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Although the knowledge points provide excellent indicators of potential risks, by themselves, they do not cover all elements of risk that a program encounters during development, such as funding instability. Our detailed reviews on individual systems normally provide for a fuller treatment of risk elements.

# Technology Readiness Levels

Technology Readiness Level	Description	Hardware Software	Demonstration Environment
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties	None (Paper studies and analysis)	None
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (Paper studies and analysis)	None
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of nonscale individual components (pieces of subsystem).	Lab
4. Component and/or breadboard. Validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.	Low fidelity breadboard. Integration of nonscale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	High fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size weight, materials, etc.). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.

**Appendix III**  
**Technology Readiness Levels**

*(Continued From Previous Page)*

<b>Technology Readiness Level</b>	<b>Description</b>	<b>Hardware Software</b>	<b>Demonstration Environment</b>
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.	Prototype—Should be very close to form, fit and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative operational environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight qualified hardware	DT&E in the actual system application
9. Actual system "flight proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	OT&E in operational mission conditions

Source: GAO and its analysis of National Aeronautics and Space Administration data.

# GAO Contact and Acknowledgments

## GAO Contact

Paul L. Francis (202) 512-4841

## Acknowledgments

David B. Best, Alan R. Frazier, and Bruce H. Thomas made key contributions to this report. Other key contributors included Robert L. Ackley, D. Catherine Baltzell, Maricela Cherveney, Tana M. Davis, Thomas J. Denomme, Arthur Gallegos, William R. Graveline, David J. Hand, Michael J. Hazard, Barbara H. Haynes, Leslie M. Hickey, John E. Oppenheim, Maria-Alaina I. Rambus, Nancy Rothlisberger, Rae Ann H. Sapp, James L. Morrison, Wendy P. Smythe, Sharon E. Sweeney, Robert S. Swierczek, and Karen S. Zuckerstein. The following staff were responsible for individual programs:

System	Primary Staff
Airborne Laser (ABL)	LaTonya D. Miller
Aegis Ballistic Missile Defense (Aegis BMD)	Randolph S. Zounes
Advanced Extremely High Frequency Satellites (AEHF)	Bradley L. Terry/Lisa P. Gardner
Active Electronically Scanned Array Radar (AESA)	Joseph E. Dewechter/Jerry W. Clark
Airborne Mine Neutralization System (AMNS)	Ian A. Ferguson/Brendan S. Culley/ Angela D. Thomas
Advanced Precision Kill Weapon System (APKWS)	John S. Warren/Thomas L. Gordon/ Michele R. Williamson
Advanced SEAL Delivery System (ASDS)	Mary K. Quinlan
Advanced Threat Infrared Countermeasure/Common Missile Warning System (ATIRCM/CMWS)	Jonathan E. Watkins/ Danny G. Owens
B-2 Radar Modernization Program (B-2 RMP)	Don M. Springman/Arthur L. Cobb
C-130 Avionics Modernization Program (C-130 AMP)	Dayna L. Foster/Christopher A. Deperro
C-5 Avionics Modernization Program (C-5 AMP)	Cheryl K. Andrew/Sameena N. Ismailjee
C-5 Reliability Enhancement and Reengining Program (C-5 RERP)	Sameena N. Ismailjee/Cheryl K. Andrew
Cooperative Engagement Capability (CEC)	Johana R. Ayers/W. William Russell
CH-47F Improved Cargo Helicopter (CH-47F)	Wendy P. Smythe/ Leon S. Gill
Compact Kinetic Energy Missile (CKEM)	Marcus C. Ferguson/Wendy P. Smythe

**Appendix IV**  
**GAO Contact and Acknowledgments**

*(Continued From Previous Page)*

<b>System</b>	<b>Primary Staff</b>
Future Aircraft Carrier (CVN-21)	Brendan S. Culley/Trevor J. Thomson
DD(X) Destroyer	J. Kristopher Keener/Angela D. Thomas
E-10A Multi-Sensor Command and Control Aircraft (E-10A)	Rae Ann H. Sapp/David R. Schilling
E-2 Advanced Hawkeye (E-2 AHE)	Gary L. Middleton/Bruce H. Thomas
EA-18G (EA-18G)	Christopher R. Miller/Brian T. Mullins
Evolved Expendable Launch Vehicle (EELV)	Maria A. Durant/Maricela Cherveney
Expeditionary Fighting Vehicle (EFV)	Alan R. Frazier/Ronald E. Schwenn
Extended Range Guided Munition (ERGM)	Shelby S. Oakley/Ronald E. Schwenn/ Margaret B. McDavid
Excalibur Precision Guided Extended Range Artillery Projectile	Lawrence D. Gaston/John P. Swain
F/A-22 Raptor	Marvin E. Bonner/Arthur L. Cobb
Future Combat Systems (FCS)	John P. Swain/ Lawrence D. Gaston/ Marcus C. Ferguson
Global Hawk Unmanned Aerial Vehicle	Bruce D. Fairbairn/Steven M. Hunter
Ground-Based Midcourse Defense (GMD)	Ivy G. Hubler
Global Positioning System II (GPS II)	Jean N. Harker/Michael L. Gorin
Heavy Lift Replacement (HLR)	Brian T. Mullins/Wesley A. Johnson
Joint Air-to-Surface Standoff Missile (JASSM)	Beverly A. Breen/Carrie R. Wilson
Joint Common Missile	Danny G. Owens/Jonathan E. Watkins
Joint Strike Fighter (JSF)	Matthew B. Lea/David R. Schilling
Joint Standoff Weapon (JSOW)	Carol T. Mebane/Bradley J. Trainor
Joint Tactical Radio System (JTRS) Cluster 1	Ridge C. Bowman/James P. Tallon
Joint Tactical Radio System (JTRS) Cluster 5	Subrata Ghoshroy/ Paul G. Williams
Joint Unmanned Combat Air Systems (J-UCAS)	Bruce D. Fairbairn/Matthew T. Drerup
Kinetic Energy Interceptors (KEI)	Randolph S. Zounes
Land Warrior	Joel C. Christenson/Candice N. Wright
Littoral Combat Ship (LCS)	J. Kristopher Keener/Angela D. Thomas
Medium Extended Air Defense System (MEADS)	Tana M. Davis
Multi-mission Maritime Aircraft (MMA)	Matthew F. Ebert/Ronald E. Schwenn/ Heather L. Barker
Mobile User Objective System (MUOS)	Richard Y. Horiuchi/Tony A. Beckham
MQ-9 Predator B	Steven M. Hunter/Travis J. Masters
National Polar-orbiting Operational Environmental Satellite System (NPOESS)	Suzanne S. Olivieri/ Carol R. Cha/ James P. Tallon
Space Based Infrared System High (SBIRS High)	Nancy Rothlisberger/Maricela Cherveney

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**Appendix IV**  
**GAO Contact and Acknowledgments**

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*(Continued From Previous Page)*

<b>System</b>	<b>Primary Staff</b>
Small Diameter Bomb (SDB)	Carrie R. Wilson/ Beverly A. Breen
Space Tracking and Surveillance System (STSS)	Sigrid L. McGinty/Tony A. Beckham
Terminal High Altitude Area Defense (THAAD)	William S. Lipscomb
Tactical Tomahawk Missile	Bradley J. Trainor/Carol T. Mebane
Transformational Satellite Communications System (TSAT)	Arturo Holguin Jr./Travis J. Masters
V-22 Joint Services Advanced Vertical Lift Aircraft (V-22)	Jerry W. Clark/Bonita P. Oden
Wideband Gapfiller Satellites (WGS)	Tony A. Beckham/Richard Y. Horiuchi
Warfighter Information Network-Tactical (WIN-T)	James P. Tallon/Ridge C. Bowman

Source: GAO.

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# Related GAO Products

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*Defense Acquisitions: Stronger Management Practices Are Needed to Improve DOD's Software-Intensive Weapon Acquisitions.* [GAO-04-393](#). Washington, D.C.: March 1, 2004.

*Defense Acquisitions: DOD's Revised Policy Emphasizes Best Practices, but More Controls Are Needed.* [GAO-04-53](#). Washington, D.C.: November 10, 2003.

*Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs.* [GAO-03-57](#). Washington, D.C.: February 11, 2003.

*Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes.* [GAO-02-701](#). Washington, D.C.: July 15, 2002.

*Defense Acquisitions: DOD Faces Challenges in Implementing Best Practices.* [GAO-02-469T](#). Washington, D.C.: February 27, 2002.

*Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes.* [GAO-01-288](#). Washington, D.C.: March 8, 2001.

*Best Practices: A More Constructive Test Approach Is Key to Better Weapon System Outcomes.* [GAO/NSIAD-00-199](#). Washington, D.C.: July 31, 2000.

*Defense Acquisition: Employing Best Practices Can Shape Better Weapon System Decisions.* [GAO/T-NSIAD-00-137](#). Washington, D.C.: April 26, 2000.

*Best Practices: DOD Training Can Do More to Help Weapon System Program Implement Best Practices.* [GAO/NSIAD-99-206](#). Washington, D.C.: August 16, 1999.

*Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes.* [GAO/NSIAD-99-162](#). Washington, D.C.: July 30, 1999.

*Defense Acquisitions: Best Commercial Practices Can Improve Program Outcomes.* [GAO/T-NSIAD-99-116](#). Washington, D.C.: March 17, 1999.

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*Defense Acquisition: Improved Program Outcomes Are Possible.* [GAO/T-NSIAD-98-123](#). Washington, D.C.: March 18, 1998.

*Best Practices: Successful Application to Weapon Acquisition Requires Changes in DOD's Environment.* [GAO/NSIAD-98-56](#). Washington, D.C.: February 24, 1998.

*Major Acquisitions: Significant Changes Underway in DOD's Earned Value Management Process.* [GAO/NSIAD-97-108](#). Washington, D.C.: May 5, 1997.

*Best Practices: Commercial Quality Assurance Practices Offer Improvements for DOD.* [GAO/NSIAD-96-162](#). Washington, D.C.: August 26, 1996.

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